BBC

Showing all month: twilight bright planets

Jupiter, Saturn and the Moon meet the Evening Star

#175 DECEMBER 2019

Sky at Night

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12 SIGHTS OF CHRISTMAS

Discover Brother Guy Consolmagno's favourite festive night sky objects

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Watch out for the Geminid and Ursid showers

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Find the legacy of Arabic astronomers in the stars

FIRST SCOPE

Bresser's Messier MCX-102 on test

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Autumn & Winter 2019

The winter skies are returning. Time to plan ahead for the winter's observing and astrophotography! With the end of summertime, and sunset and the Pleiades rising around 4.30pm at the beginning of the month, there;s lots to see. Orion clears the horizon around 10pm. The Widescreen Centre is a real showroom you can visit and see the latest priduwhich cts and get expert advice before you buy.
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Welcome

Join our tour of the 12 celestial sights of Christmas

Christmas, that time of good news, provides just that for amateur astronomers this year. With a new Moon on the 26th, the skies will be at their darkest over the festive season and anyone who's lucky enough to get some new observing kit under the tree has a great opportunity to try it out. What better way than with Director of the Vatican Observatory and author of *Turn Left at Orion*, Brother Guy Consolmagno, whose tour of 12 of December's best sights begins on page 28.

New Moon late in the month means that on the 13th/14th, peak night for the Geminid meteor shower, it will be just past full. Its light will affect the number of meteors seen this year but, as it's a strong shower, it's still worth watching out for Geminids in darker areas of the celestial sphere. The less famed Ursid meteor shower gives meteor watchers another chance to catch a shooting star, peaking in nice dark skies on the 22nd/23rd, during the Moon's thin waning crescent phase. See page 47 of the Sky Guide for more.

As well as shooting stars, December sees the arrival of a 'Christmas Star' – in the form of Venus, shining brightly in early evening skies all month. There are eye-catching close encounters with Saturn and the thin crescent Moon detailed in the Sky Guide on page 43, and Director of the British Astronomical Association's Mercury and Venus section, Paul Abel, examines amateur observations of bright spots on the planet's night side on page 65. We'll see more of Venus in the New Year as it continues to be a feature of evening skies during winter and spring.

Enjoy the issue and season's greetings!

Chris Bramley, Editor

PS Our next issue goes on sale 19 December.

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Editorial enquiries
+44 (0)117 300 8754
9.30am–5.30pm, Mon–Fri

Advertising enquiries
+44 (0)117 300 8145

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New to astronomy?

To get started, check out our guides and glossary at
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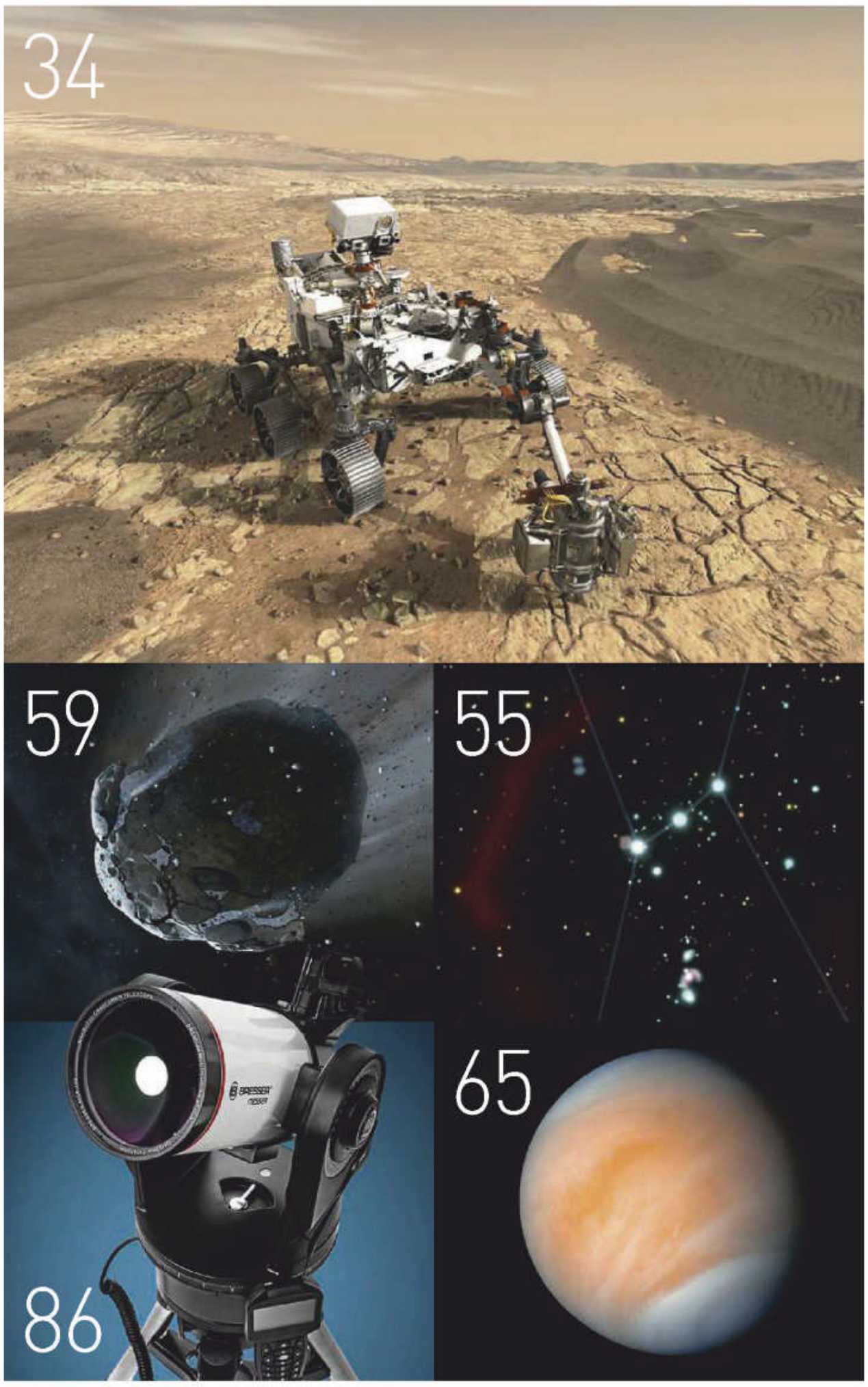


This month's contributors

Brother Guy Consolmagno

Vatican Observatory director

Brother Guy selects 12 seasonal night-sky treasures to enjoy with your new telescope. See page 28

Dr Danielle Adams

Cultural astronomer

Danielle explores the rich heritage of astronomy on the Arabian Peninsular. See page 40

Shaoni Bhattacharya

Science journalist

Shaoni enjoys the latest book by Maggie-Aderin Pocock, aimed at pre-teen children. See page 94

Paul G Abel

BAA director, Mercury & Venus

Paul gives valuable tips on how to help search for volcanic activity on Venus. Turn to page 65

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/83F4F8F/** to access this month's selection of Bonus Content.

DECEMBER HIGHLIGHTS

The Sky at Night: Question Time

Watch an hour-long special in which *The Sky at Night* team joins guests for a Q&A in front of a studio audience.

Video interview: ESA Solar Orbiter

We speak to Prof Richard Harrison about the new ESA spacecraft that will orbit and image our host star like never before.

NEW Southern Hemisphere Guide

Download this month's all-sky chart, including a guide to the best targets visible in southern skies over the coming weeks.

Astrophoto gallery, extra EQMOD files, binocular tour, observing forms, deep-sky tour chart, desktop wallpapers...**and much more**

PLUS: Every month

Night-sky highlights

Pete Lawrence and Paul Abel discuss the top sights to see this month.

A galactic CHRISTMAS present

Astronomy never stops; not even on 25 December

HUBBLE SPACE TELESCOPE, 28 OCTOBER 2019

This Christmas Day marks 182 years since the discovery of spiral galaxy NGC 1706 by British astronomer John Herschel, who could not possibly have predicted the same galaxy would be observed nearly 200 years later by a huge telescope orbiting Earth.

Hubble astronomers have just released this beautiful image of the galaxy, which is located around 230 million lightyears away in Dorado (The Swordfish), a southern-sky constellation laden with deep-sky objects including a fair part of the Large Magellanic Cloud. This image was captured by Hubble's Advanced Camera for Surveys, taking separate exposures in visible and infrared light.

NGC 1706 is one of a trio of galaxies called the ESO 85-38 group. Zoom outwards and they are part of the 50-strong LDC357 group, a small subset of galaxies gravitationally bound and relatively close to one another.

About half of the galaxies we know of belong to a certain galaxy group, making these huge structures quite common in the Universe. Our home Galaxy, the Milky Way, belongs to the Local Group, which also contains the Andromeda Galaxy, the Small and Large Magellanic Clouds and the Triangulum Galaxy.

As you tuck into this year's Christmas dinner, cast your mind back nearly two centuries to the astronomer John Herschel, who at that same moment may have been pointing his telescope to the sky and casting a human eye on this galactic beauty for the first time.

MORE ONLINE
A gallery of these and more stunning space images

ESA/HUBBLE & NASA/A. BELLINI ET AL

◁ Heart of the Milky Way

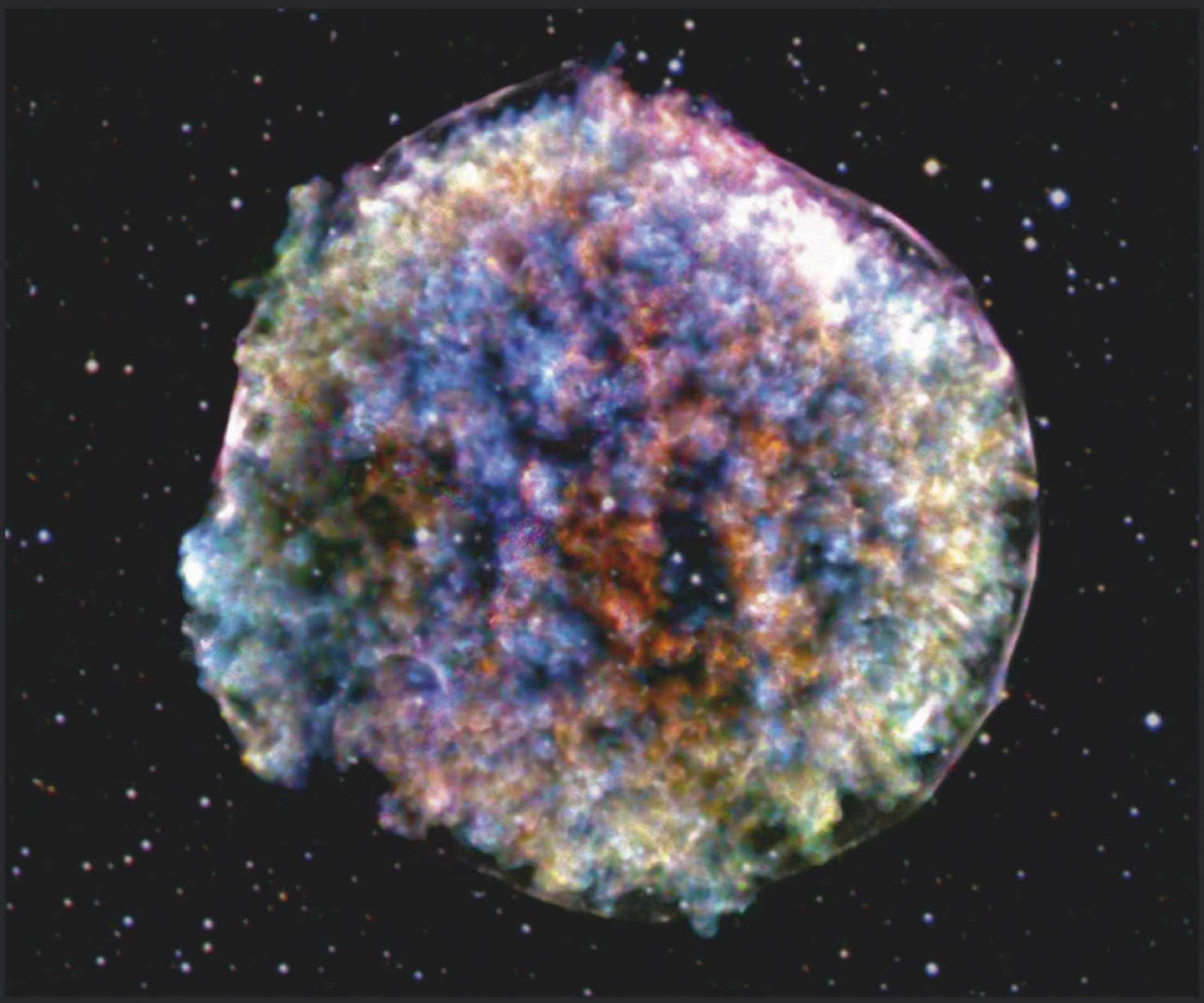
SPITZER SPACE TELESCOPE, 9 OCTOBER 2019

Brimming with stars, this is the crowded centre of our Milky Way. It's one of the last images expected from Spitzer before its retirement. After launch in 2021, the infrared capabilities of its successor, the James Webb Space Telescope, promise to penetrate interstellar dust and gas even further.

▽ Lumpy death star

CHANDRA X-RAY OBSERVATORY AND SLOAN DIGITAL SKY SURVEY, 17 OCTOBER 2019

Tycho as you've never seen it before: the remnant of a supernova 13,000 lightyears away in Cassiopeia. The lumpy appearance in this image may be the star's explosive death or an after effect. One theory is that the lumps are the result of an explosion with multiple ignition points – like millions of dynamite sticks igniting simultaneously.



NASA/JPL-CALTECH/SUSAN STOLOVY (SSC/CALTECH) ET AL, X-RAY: NASA/CXC/RIKEN & GSFC/T. SATO ET AL; OPTICAL: DSS, ALMA (ESO/NAOJ/NRAO) ALVES ET AL, ALMA (ESO/NAOJ/NRAO) P. JACHYM (CZECH ACADEMY OF SCIENCES) ET AL

◁ Secret lives of newborn stars

ATACAMA LARGE MILLIMETER/SUBMILLIMETER ARRAY, 4 OCTOBER 2019

Stars are born when dense dust clouds collapse under gravity, leaving a dusty disc in orbit out of which planets may eventually form. These bright dots are two such discs, surrounding a pair of newborn stars that are feeding off loops of cosmic material. The dots have a radius similar to that of our Solar System's asteroid belt.

▽ Tentacle trails

VERY LARGE TELESCOPE, ATACAMA LARGE MILLIMETER/ SUBMILLIMETER ARRAY, HUBBLE SPACE TELESCOPE, 30 SEPTEMBER 2019

Galaxy ESO 137-001 is a 'jellyfish' galaxy; named because starry appendages dangle from its disc-like tentacles. This is the first high-resolution map of tangled streams of gas spewing out from a spiral galaxy and shows trails of hydrogen in purple hues, and orange-red hotspots of carbon dioxide. About 260,000 lightyears long, the trails are a result of ram-pressure stripping where gas is torn from the galaxy as it ploughs through cosmic material.

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BULLETIN

The effects of the collision between two planets in the system BD +20 307 continue to be observed after a decade

NASA/SOFIA/LYNETTE COOK

Catastrophic collision

BETWEEN TWO EXOPLANETS

The crash has dramatically changed the system in just a decade

The dramatic aftermath of a collision between two exoplanets has been spotted in recent observations of BD +20 307, a double star system 300 lightyears away.

The planetary system first attracted curiosity in 2005 when astronomers noticed signs of warm dust around the stars. Usually, hot discs are found around much younger stars, which are still forming planets. But BD +20 307 is a mature one billion years old. Any dust should have long cooled off. Instead it seemed the system has been replenished with hot debris in the wake of two planets colliding.

Intriguingly, recent measurements of its infrared brightness – an indicator of how warm the dust is – by the SOFIA (Stratospheric Observatory for Infrared Astronomy) telescope show the disc's brightness increased by 10 per cent over the last decade, suggesting the effects of these collisions go on long after the initial impact.

"The warm dust around BD +20 307 gives us a glimpse into what catastrophic impacts between rocky exoplanets might be like," says Maggie Thompson from the University of California, Santa Cruz, who led the study. "We want to know how this system evolves after the extreme impact."

It's thought that a similar event occurred in our own Solar System, when a Mars-sized object slammed into the proto-Earth. As the resulting cloud of debris settled, it formed the Moon.

"This is a rare opportunity to study catastrophic collisions occurring late in a planetary system's history," says Alycia Weinberger from the Carnegie Institution for Science in Washington, who also helped lead the project. "The SOFIA observations show changes in the dusty disc on a timescale of only a few years."

www.sofia.usra.edu

Comment

by Chris Lintott

The weirdest thing about BD +20 307 is that it's more than a billion years old. We see discs of dust, left over from the star formation process, around young stars all the time, but the material seen here can't have survived from the time of the star's formation.

That's why the researchers believe we're seeing debris from a collision between two planets, but any such event must have happened after a billion years of quiet life. It's true that our Solar System's early years were marked by chaotic collisions, but round here these big changes happened early.

BD +20 307 is a reminder that our stability might be an illusion. As we study it more, we'll understand how common such events are, and might look nervously at our neighbours!

Looking for life: in 2017 Cassini analysed icy spray in water plumes above the moon Enceladus

NASA/JPL-CALTECH X 2, NASA ESA AND D. JEWITT (UCLA), CEDIC TEAM/BERNHARD HUBL/CCDGUIDE.COM

Ice world has ingredients of life

Saturn's moon Enceladus could be our best shot at finding life beyond Earth

A new kind of organic compound has been found in plumes of water bursting from Saturn's icy moon, Enceladus, according to the latest interpretation of data from the Cassini spacecraft.

The plumes, first discovered in 2005, are believed to originate from hydrothermal vents on the floor of the ocean that lies beneath the moon's ice crust. These allow gases trapped in the moon's core to escape and interact with the rock of the ocean floor, creating new molecules while mixing with the chemicals already there. As the gas rises, it carries this material as it forces its way up through the cracks in the crust.

"The gas bubbles come from the depths to the surface and when they burst, the material goes upwards – just like if you open the lid of a cola bottle," says Nozair Khawaja from the Free University of Berlin, who led the research.

These jets of water eject high above the moon, feeding into the planet's outer E-ring. In 2017, the Cassini spacecraft was able to fly through one of these plumes, sampling the water with its Cosmic Dust Analyzer (CDA) instrument. Khawaja's team is now using these measurements to determine what molecules are in the water.

Last year, the team found some organic molecules within the plume water but these were large and insoluble, meaning they were unlikely to take part in biological reactions.

"This time we found soluble, small organic molecules that carry oxygen and nitrogen," says Khawaja. "Such chemicals are precursors to amino acids. I can't say that we have found life on Enceladus, but what we have found has great implications."

While the chemicals don't necessarily originate from biological activity, similar chemicals around Earth's hydrothermal vents combine together to form amino acids.

"On Enceladus, we certainly have the precursors of such biological molecules that create amino acids in Earth's oceans. And they are under similar conditions of temperature and pressure. If they are there – and if they are similar to what we have found in Earth's oceans – then there are high chances that a future space mission could find biological molecules there. It's giving hope for the future."

https://solarsystem.nasa.gov/missions/cassini

▲ The Hubble Space Telescope's image of 2I/Borisov shows the comet 420 million km from Earth

Hubble captures interstellar comet

The comet already has signs of a coma and tail

The best image yet of interstellar comet 2I/Borisov was taken by the Hubble Space Telescope on 12 October, showing this latest visitor is acting much more like a comet than previous galactic interloper 'Oumuamua, which passed by back in 2017.

"'Oumuamua looked like a bare rock, but Borisov is really active – more like a normal comet," says David Jewitt from the University of California, LA. "It's a puzzle why these two are so different. There is so much dust on this thing we'll have to work hard to dig out the nucleus."

Hubble captured the comet when it was still 420 million km from Earth. Astronomers will study the comet throughout its trip through our Solar System, including the closest approach to the Sun on 7 December, hoping to gain insight into what the planetary system that created it was like.

www.spacetelescope.org

Milky Way stole dwarf galaxies

Astronomers have discovered that several dwarf galaxies currently orbiting the Milky Way were kidnapped from its companion galaxy, the Large Magellanic Cloud (LMC).

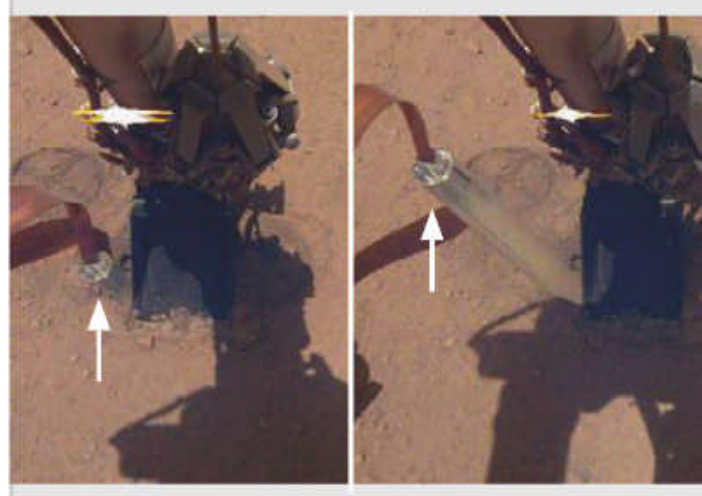
The team from the University of California, Riverside (UCR) made the discovery by studying the latest data from Gaia, a space telescope accurately measuring the positions and velocity of over one billion stars. Using the motions of stars in the dwarf galaxies surrounding the Milky Way, the team was able to create a computer simulation showing several of them were once part of the LMC. Two of these were the bright dwarfs Carina and Fornax, while the remaining four were ultrafaint galaxies with few stars and made mostly of dark matter.

The Large Magellanic Cloud was once home to dwarf galaxies that were kidnapped

"If so, many dwarfs came along with the LMC only recently, that means the properties of the Milky Way satellite population just one billion years ago were radically different, impacting our understanding of how the faintest galaxies evolve," says Laura Sales from UCR, who helped with the study.

www.ucr.edu

NEWS IN BRIEF



InSight feels the heat

The heat probe on NASA's InSight Martian lander has popped out of the ground. The probe was supposed to hammer itself into the soil but has struggled to find a purchase. During October, the InSight team used the lander's robotic arm to 'pin' the probe in place and appeared to be making progress, only for the probe to back up halfway out again.

Nobel prize for astronomers

The 2019 Nobel Prize for physics was awarded to three space scientists on 8 October – James Peebles, for his theoretical work on cosmology relating cosmic background radiation to the Big Bang; and Michel Mayor and Didier Queloz, for their discovery of the first planet around a Sun-like star.

Milky Way explosion

A beam of energy exploded out of the Milky Way 3.5 million years ago, shooting a cone of radiation out from its centre. "This shows that the centre of the Milky Way is a much more dynamic place than previously thought. It is lucky we're not residing there!" says Lisa Kewley from the ARC Centre of Excellence. Find out more on page 17.

NEWS IN BRIEF

NASA plans lunar rover

NASA has announced a new lunar rover that will help pave the way for its Artemis mission. The Volatiles Investigating Polar Exploration Rover (VIPER) will be the size of a golf cart and will look for water at the Moon's southern pole using a 1m-long drill. It's expected to land in December 2022 and spend at least 100 days on the lunar surface.

Saturn's new moons

Twenty new moons have been discovered in orbit around Saturn, taking the total up to 82. "We are now completing the inventory of small moons around the giant planets," says Scott Sheppard from the Carnegie Institution for Science. "They play a crucial role in helping us determine how our Solar System's planets evolved."

Dark energy investigator

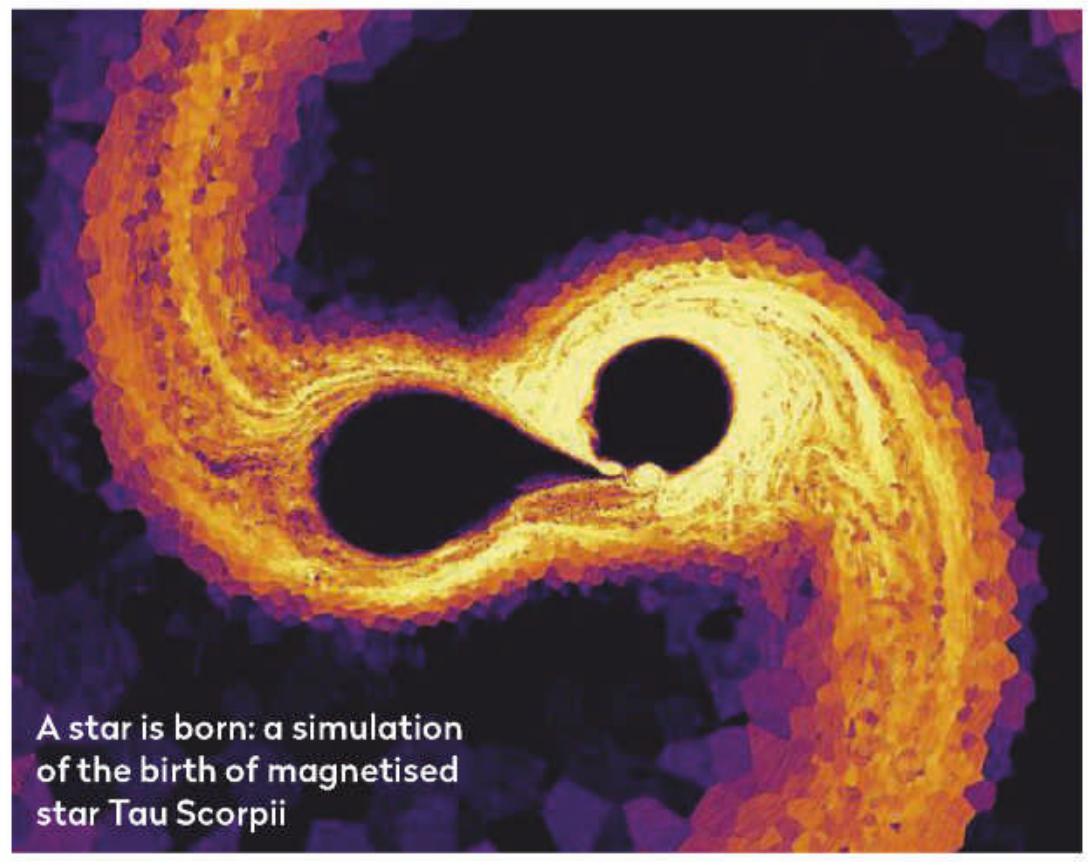
An instrument capable of looking at 5,000 galaxies every 20 minutes began operation on 27 October. The Dark Energy Spectroscopic Instrument (DESI) will look at over 30 million galaxies to measure how fast they are moving away, creating a map of how the Universe is expanding to help researchers investigate dark energy.

NASA AMES/DANIEL RUTTER, © OHLMANN/SCHNEIDER/RÖPKE, NASA

BULLETIN

Do crashing stars create magnetars?

New technology reveals how magnetic stars are formed



A star is born: a simulation of the birth of magnetised star Tau Scorpii

Enormously magnetic stars, known as magnetars, appear to be created by two stars crashing together, according to a novel computer simulation.

Astronomers have long thought stellar mergers could be responsible for creating magnetars, but have had to wait until now for computer simulations to be refined enough to test the theory. The team digitally recreated the birth of Tau Scorpii, a highly magnetised star known to have been created by two other stars combining together. These simulations showed that the turbulence during this merger formed a strong magnetic field, which was then trapped within the resulting star.

"Magnetars are thought to have the strongest magnetic fields in the Universe – up to one hundred million times stronger than the strongest magnetic field ever produced by humans," says Freidrich Röpke from the Heidelberg Institute for Theoretical Studies, who helped with the research.
https://www.h-its.org/

First all-woman spacewalk a success

The first all-female spacewalk took place on 18 October. NASA astronauts Christina Koch and Jessica Meir spent seven hours and 17 minutes outside the ISS, replacing a faulty battery unit.

"Inclusion of diversity in any group is really how you get the job done," Meir said after the spacewalk. "If you have different ways of looking at things... that is going to lead to higher mission success."

Astronauts Christina Koch (left) and Jessica Meir prepare for their spacewalk

Koch was meant to make a similar historic spacewalk back in March this year, until fellow astronaut Anne McClain realised she needed a different sized spacesuit to the one prepared, and rescheduled the rota.

The historic event comes as NASA is planning its Artemis mission, which aims to place the first woman on the Moon by 2024. The agency recently unveiled designs for a new spacesuit, which has been designed to give astronauts of all shapes, sizes and genders mobility on the surface of the Moon, while protecting them from the harsh lunar environment.
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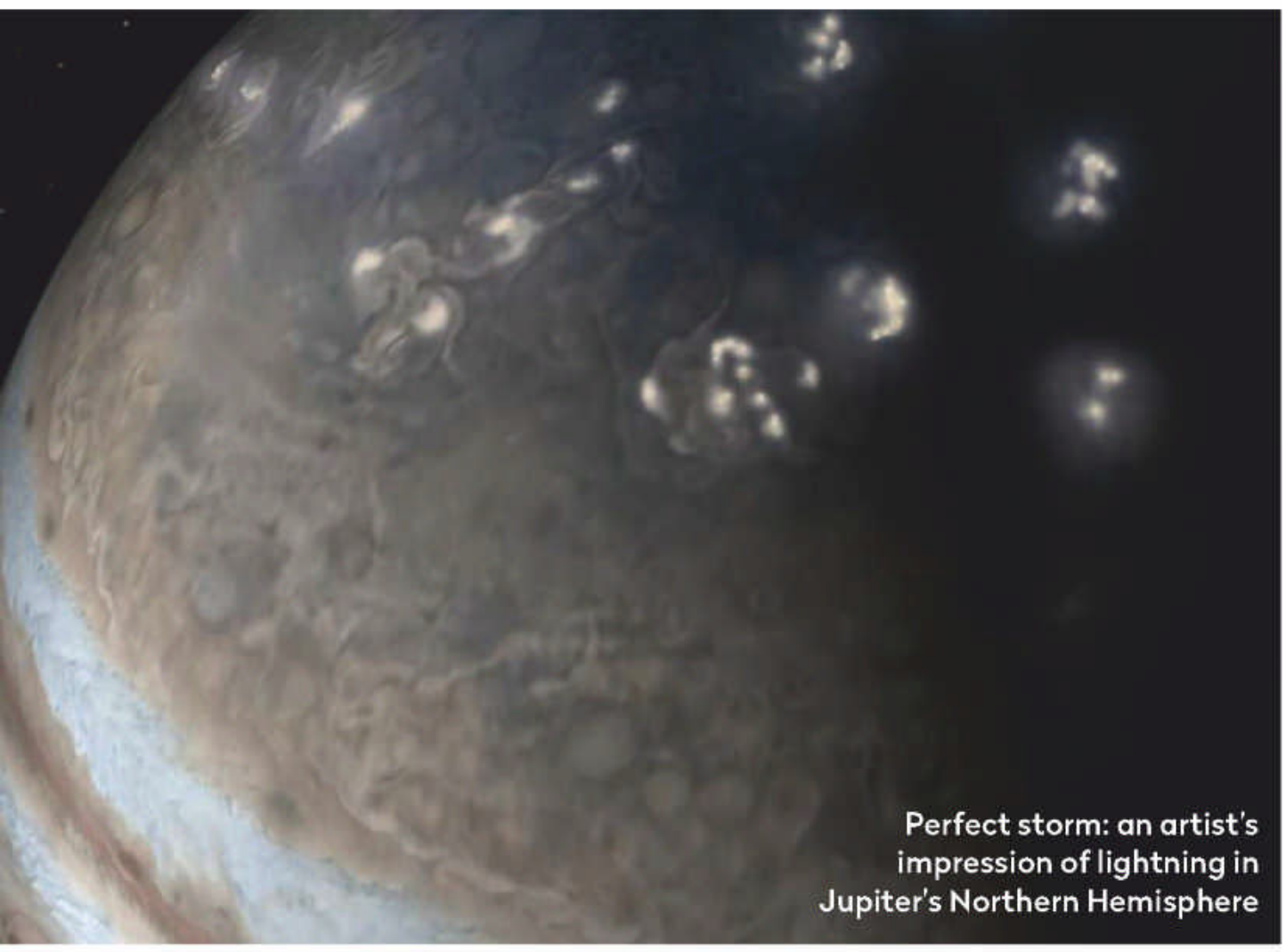


Perfect storm: an artist's impression of lightning in Jupiter's Northern Hemisphere

It was a dark and stormy planet...

Exoplanets could need both clear and storm-laden skies to host life

One of my great pleasures is huddling up safe inside, while an awesome lightning display tears the heavens apart with booms of thunder. Earth is not unique in generating such electrical storms in its atmosphere. Lightning has been observed in the cloud decks of both Jupiter and Saturn, inferred on Uranus and Neptune, and is also debated to be present on Venus.

Lightning occurs if collisions between cloud particles create enough of an electrical 'potential difference' that it overcomes the insulating properties of the air, allowing a discharge to spark. On Earth it's not only the turbulent convection within storm clouds that can generate the necessary potential differences, but also the rising ash plumes of volcanic eruptions.

But the sparks of lightning are only one aspect of Earth's dynamic atmosphere building up steep differences in electrical charge. In fact, the entire planet Earth behaves like a giant electric circuit, known as the global atmospheric electrical circuit (GEC). Lightning shoots electrons towards the ground, and so thunderstorms generate an electric potential difference – the planet surface becomes negative and the ionosphere (the high upper atmosphere) becomes positive. Just like across the two terminals of a battery, this voltage drives an electrical current of charged particles between the ionosphere and the surface. Crucially, a 'fair weather current' is needed to complete this circuit between the Earth's negatively-charged surface and positive ionosphere. The GEC needs lighting storms and regions of clear skies.

Storm chasing

This GEC has an effect on weather patterns and atmospheric physics. Lightning can drive a lot of key gas chemistry – on Earth, for example, it fixes nitrogen into a form accessible by life. So what conditions might extrasolar planets need in order to also support such a GEC – an important consideration if we are to understand exoplanet atmospheres?

Christiane Helling at the University of St Andrews has been researching this question. Many exoplanets are predicted to have layers in their atmospheres cool enough to condense cloud particles, which also presents the possibility of lightning storms. But some of these atmospheres are very alien – some exoplanets orbit their host star so closely that their surface is molten magma and the cloud particles are a mix of solidified minerals.

Lightning has been observed in the cloud decks of both Jupiter and Saturn, inferred on Uranus and Neptune, and may be present on Venus

In general, Helling concludes that gas giants, or the super-Earths that are completely overcast, may not be able to support a fair weather current and so would have no GEC like Earth's. Other exoplanets, where one side is permanently facing their star, would be so hot on their daylight side that nothing can condense as a liquid, and clouds are only possible on the night side. But a fair-weather current might persist on this day side, with lightning in the cloudy night side, and so planets with this hemisphere-by-hemisphere separation may develop a GEC on a scale far larger than Earth's.

Characterising these processes is important for our understanding of the atmospheric dynamics on exoplanets, and which worlds might experience truly epic thunderstorms.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Lightning in other planets* by Christiane Helling. **Read it online at https://arxiv.org/abs/1910.12722**

NASA/JPL-CALTECH/SWRI/JUNOCAM, JAMES JOSEPHIDES/THORSTEN TEPPER-GARCIA/ASTRO 3D

Our black hole's recent eruption

It seems our Galaxy was a different place just a few million years ago

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night*

The fearsome reputation of black holes as merciless devourers of all they encounter, bequeathed by science fiction, isn't always deserved. The supermassive black hole at the centre of our Galaxy sits there meekly, with no trace of menace to the stars which orbit it. But this month's paper, led by The University of Sydney's Josh Bland-Hawhorne, adds to the growing pile of evidence that such calm is only temporary, and that 3.5 million years ago the centre of the Milky Way may have looked very different.

What's remarkable is that this new evidence hasn't come from staring at the Milky Way's centre itself, but instead looking away from it. The team used the Hubble Space Telescope to identify distant quasars which happened to lie behind a feature called the Magellanic Stream. The stream stretches across an arc that covers more than half the sky, and its composition and position suggest that it came from one of the two Magellanic Clouds, our Galaxy's largest satellite systems. The stream seems to be the result of the gravitational dance the two Clouds have completed over the years, as they orbit and interact with the larger Milky Way.

The calm of our supermassive black hole is only temporary – 3.5 million years ago the Milky Way's centre would have been very different

An unknown source

As light from background quasars passes through the stream en route to us, it is absorbed by the gas; the details of that process tell us about the state of the stream, and there are surprises in store. For much of its length, it turns out that the stream's gas is ionized (excited) by some unknown source. We need to find something capable of irradiating this remote gas with high-energy radiation to explain what's seen.

So what's the source? One possibility would be luminous X-ray sources in the Large Magellanic Cloud, which is a large galaxy in its own right, but the geometry of the ionized parts of the stream doesn't seem to fit. Instead, the authors suggest that the Milky Way lived through a period when its black hole was growing, accreting material which would build up in a hot, bright accretion disc that is absent today.

The Milky Way's central black hole must have been accreting at a substantial fraction of the Eddington Limit, the theoretical maximum rate at which such an object in normal circumstances can grow. Our Galaxy, seen from the outside, would have been a Seyfert, firmly classified as an active galaxy.

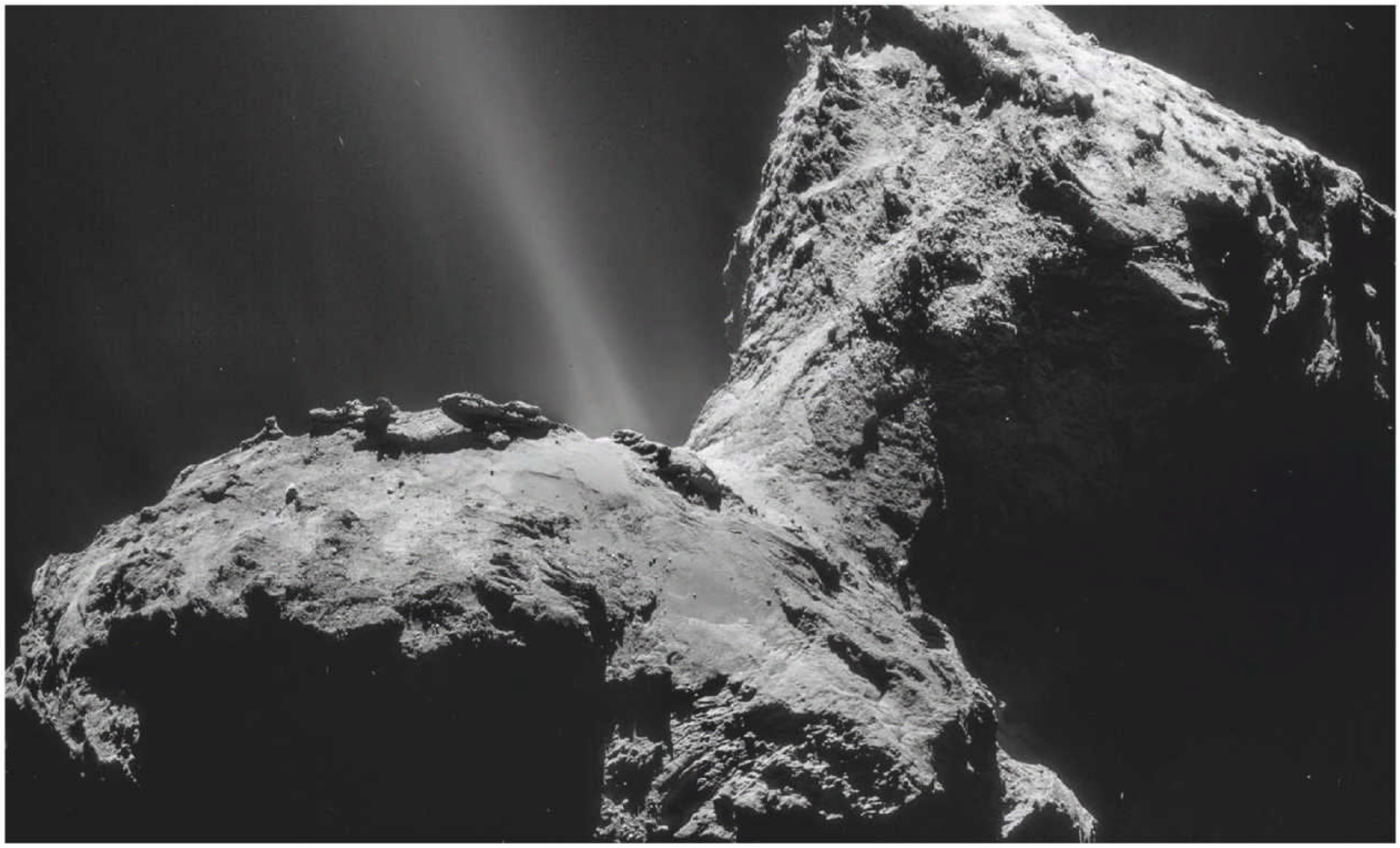
This picture fits other recent discoveries including the presence of the 'Fermi bubbles', enormous structures centred on the Galactic centre that may represent a shock wave from this violent part of our past, still heading out into space. And if such an event happened in the last few million years, then it's unlikely to have been a one-off. Galaxies can change from calm dormancy to dramatic activity rapidly. This is the key to understanding the outstanding mysteries about how galaxies and their black holes grow together.

A cataclysmic flare, propelled from the heart of the Milky Way 3.5 million years ago, was felt 200,000 lightyears away

Chris Lintott was reading... *The large-scale ionization cones in the Galaxy* by Joss Bland-Hawthorn et al. **Read it online at https://arxiv.org/abs/1910.02225**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



▲ The Rosetta mission found molecules that predate our Solar System on Comet 67P/Churyumov-Gerasimenko

ESA/ROSETTA/MPS AND ESA/ROSETTA/NAVCAM, NASA/JPL, EHT COLLABORATION

In November's episode of *The Sky at Night*, the team marked the end of ESA's Rosetta mission, talking to **Prof Kathrin Altwegg**, the principal investigator for the spacecraft's ROSINA instrument

Almost exactly three years after the landing of Rosetta on 67P/Churyumov-Gerasimenko, the last Science Working Team (SWT) meeting has ended, marking the official end of the mission. Twenty years after our instrument ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) was selected for flight, it ended its life on the surface of the comet when Rosetta crash-landed on 67P/Churyumov-Gerasimenko back in 2016. This marked a proud and sad moment, as we had grown fond of ROSINA. We had lived with it for many years, suffering through difficult times and finally witnessing its superior performance at the comet. ROSINA, a very complex instrument with two mass spectrometers and a pressure sensor, combined the expertise of many international institutes from all over the world. Looking back, it was an intense time, never boring, full of surprises and full of challenges. We were kept more than busy with technical, managerial and human problems, unforeseen hiccups in operations, planning for the time around an unpredictable comet and, finally, operating an instrument in an unknown environment. Three years after the final landing of Rosetta, and despite the fact that we still have to analyse a large part of the data, we can proudly state that the effort and money spent on this crazy endeavour was clearly worth it.

ROSINA analysed the composition of the volatile atmosphere of the comet. Our expectations about the nature of the molecules we were going to see was based on observations from the Giotto mission to Comet Halley more than 30 years ago, as well as remote sensing from Earth. In reality, our findings turned out to be more complex. We detected a full zoo of complex molecules, surprising in a body that is believed to consist of the most primitive material in our Solar System. Large aromatic ring molecules like naphthalene, long carbon chains, alcohols, sulphur

Kathrin Altwegg is a professor of planetary science at the University of Bern

species and many more 'animals' populate our zoo. ROSINA even detected the amino acid glycine.

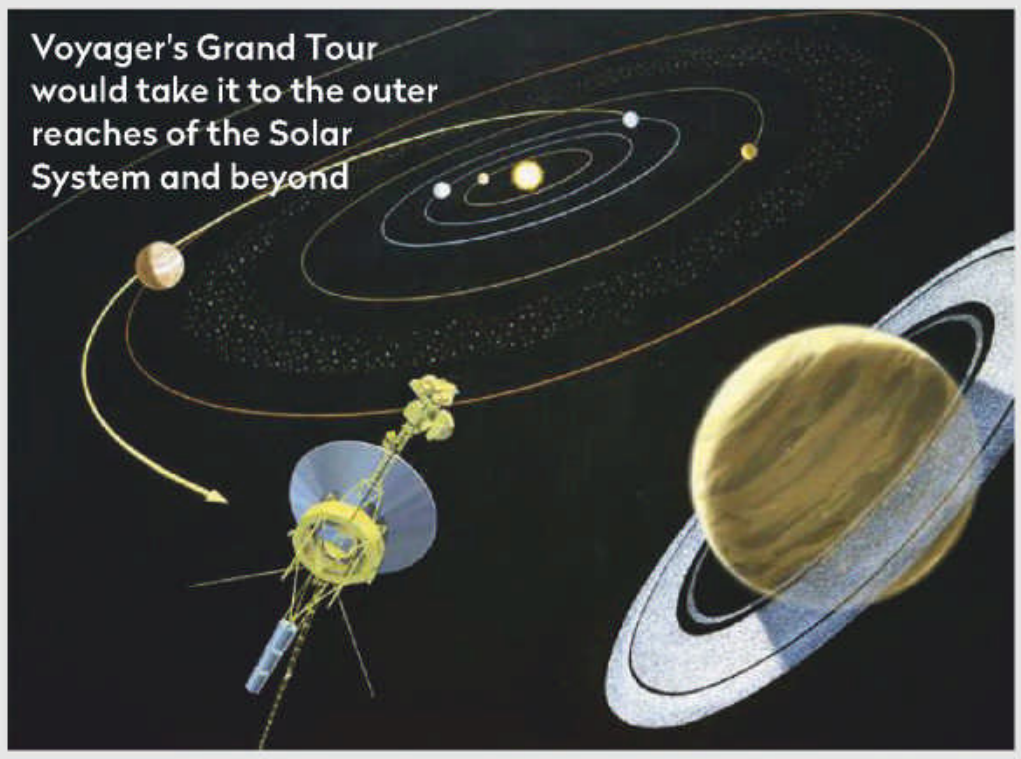
Most molecules we saw seem to predate the origin of our Solar System, making them 'universal' as they formed without Sun or planets. Comparing the signatures of noble gases between Earth's mantle, terrestrial atmosphere and 67P/Churyumov-Gerasimenko allows us to estimate the amount of cometary material delivered to Earth. Even if we can safely state that the bulk of terrestrial water is not cometary, comets like 67P/Churyumov-Gerasimenko may have sparked life (us humans included) by delivering significant amounts of organics.

Each compound detected in the cometary atmosphere tells its own tale. Together they show us the pathway from long-dead stars, to the interstellar medium, to our baby Sun and finally, planets and life. It's a touching story as it allows us to glimpse back to our own origin, more than 4.6 billion years ago. All this would not have been possible without the engineers, technicians and scientists, many of them retired by now, who dedicated part of their life to Rosetta and ROSINA.

The heritage of Rosetta and ROSINA will remain important for a long time to come, especially as data is now carefully archived and open to the public.

Looking back: The Sky at Night

December 1969



Voyager's Grand Tour would take it to the outer reaches of the Solar System and beyond

In the 2 December 1969 episode of *The Sky at Night*, Patrick was joined by the head of NASA's robotic space programme, WH Pickering. The agency was planning on taking advantage of an alignment of the outer planets in the 1970s. It would be possible for a single spacecraft to fly past all four in what was being referred to as The Grand Tour.

As well as saving money by sending one mission instead of four, the spacecraft could use each inner planet to gain a gravitational speed boost, allowing it to reach Neptune in 13 years, rather than the 30 it would have taken otherwise.

NASA had set up a working group to plan a mission to take advantage of the alignment, eventually coming up with Voyager – a pair of spacecraft which launched for the outer planets in 1977. Today, both spacecraft are still travelling onward, and have passed out beyond the protective bubble of our Sun's magnetic influence. Voyager 1 is currently 18.8 billion km away from Earth and Voyager 2 is 15.3 billion km away.

Review of the Year

As we approach the end of another year, presenters Chris Lintott and Maggie Aderin-Pocock look back at some of the major stories in space exploration over the past 12 months. From New Horizons' flyby of Kuiper Belt Object Ultima Thule on the Solar System's edge, to the release of the first ever image of a black hole and the discovery of geological activity on Mars, 2019 has certainly been one to remember.

BBC Four, **10 December**, 10pm (first repeat BBC Four, **14 December**, 7.30pm)
Check www.bbc.co.uk/skyatnight for subsequent repeat times

▲ **The first ever image of a black hole made headlines back in April**

Emails – Letters – Tweets – Facebook – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

This month's top prize:
four Philip's books

PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2020 Stargazing*.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

MESSAGE OF THE MONTH

Great balls of fire!

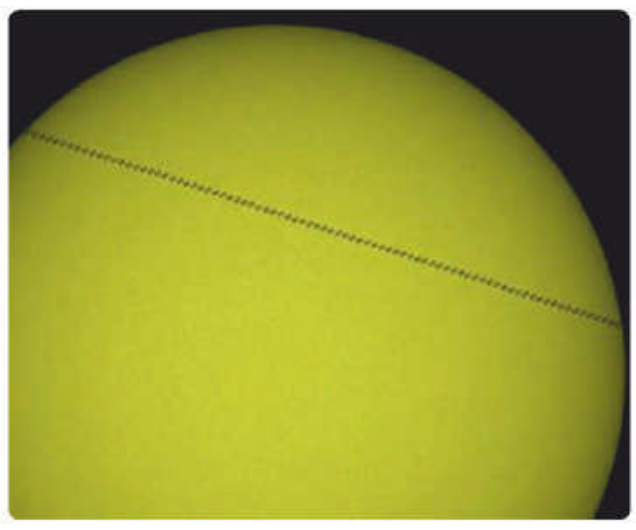
On 4 October I was leaning out of my window, taking long-exposure photos of the night sky, when this incredible fireball burst into view right in front of the camera. I have never seen anything like it – there were perhaps a dozen mini-fireballs all travelling together, forming and exploding in a kind of chain reaction. If you look at the photo you can see some of them fragmenting and breaking away from the others. It took about 25 seconds for the fireballs to cross the sky and disappear behind the house, still burning brightly. The next day I learned that the fireball had also been seen in Cork, Limerick and Galway and that it was likely to be the rocket body of a Chinese satellite launched in 2016 burning up on re-entering the atmosphere.
Gil Murray, Doonfoot, Ayr


Lighting up the sky: the remains of a Chinese satellite

What a great image of the event, Gil. Ireland has had quite a month of it, also witnessing a green tinged meteor fireball in the night sky on 28 October. **– *Ed.***

Tweets

Daniel Tackley
@dtackley • 28 Oct
This morning the #ISS passed between the sun and me in my back garden creating a solar transit. The sky was clear and I was waiting and I captured a video and then stacked the frames to produce this image. @skyatnightmag @BBCStargazing @astro_timpeake



Birth of a star

I read your magazine every issue and I'm an armchair astronomer so, therefore, learn all from you, plus NASA and ESA's excellent publications. One thing that has been puzzling me is star formation. One phrase I come across a lot is "...when stars switch on". But how long does this take? Once fission commences is it like the light from a light bulb, one minute dark and one minute bright? Or is it like a glowing ember, getting brighter like getting a camp fire going? Once it starts how long is it before we can officially call it a star: minutes, hours, weeks, years, millennia or millions of years? Once we have powerful enough space telescopes, could we timelapse the birth of a star?
Stephen Tilley, Bath

When the core reaches the right pressure, fusion begins like turning on a light switch. But it takes tens of thousands of years for that energy to make it to the surface of the star, so a space telescope timelapse would be a long time in the making! **– *Ed.***

Self-reflection

Certainly astronomy has a role in counteracting climate change ('Astronomers, your planet needs you!', November), but it must also put its own house in order. Astronomers for instance do a lot of travelling, often involving long-distance flying. We have eclipse chasers, and professional astronomers going from telescope to telescope across the globe with astronomical carbon footprints. Space tourism is seen as a great goal, instead of an immense increase in the global carbon footprint. We do conservation and science a disservice if we are uncritical in our use of energy, just because it's astronomy.
Derek Smith, Forest Gate, London

THE MIDNIGHT SKY AT LONDON, LOOKING NORTH, DECEMBER 15.

London lights

Thanks for Darryl Quantz's piece on climate change (November). I feel that he did, however, miss one point that affects astronomers and is also having a detrimental effect on wildlife. This is light pollution. Evidence shows that artificial light at night (ALAN) interferes with insect development, movement, foraging and reproductive success and is one of the factors contributing to the approx. 75 per cent loss in insects over the last 30 or so years. ALAN has also been shown to affect other animals too, including fish, birds and mammals, with nocturnal creatures being badly affected. The picture (above), taken from the 1869 book *The Midnight Sky: Familiar Notes on Stars & Planets* by Edwin Dunkin, shows a time when the Milky Way was visible to the naked eye over the City of London. Today, this view has disappeared. There may be a glimmer of light as legislation in other countries such as France and Austria provides guidance in dealing with the issue of light pollution, which fellow stargazers can help to gain more traction on here in the UK.

Ivor Trueman, Leeds ▸

ON FACEBOOK

WE ASKED: What would you most like for Christmas this year?

Andrew Noble A cloud neutraliser.

David Taylor A Wi-Fi camera lens for my telescope so I can take photos with my phone.

Bryan Sisson A telescope that works on the same principal as an 'Alexa' [Amazon Echo] so it operates at your command.

Martin Donaghy Fewer street lights.

Danner Coolsteel Two more arms.

Darren Austin I'm new to the photography side of things so I'd like a guided mount.

Caroline Brooks A spotting scope.

Garry J Carr Interstellar travel.

Calvin Hall A 24-inch f/3.4 John Nichol mirror.

Michael Woodcock Clear skies.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

When I image planets with my Celestron CPC 925 they disappear from view after a few seconds. I finish my alignment pointing up and right to take out backlash, but what else can I do?

DAVID HEWITT

The Celestron CPC 925 is a Schmidt-Cassegrain telescope mounted on a Go-To altazimuth mount, which should be capable of keeping a planet in the field of view for minutes rather than seconds. However, it would appear that the mount is not tracking correctly, if at all. You already have a strategy in place for taking up backlash but make sure that there isn't still a lag before the drive takes up the slack.

Next, check your GPS is right and that the correct hemisphere, location, date, time and daylight savings settings are in place. If these settings are correct then after the mount has confirmed you have located your chosen planet, you could try pressing the 'Enter' key again to start the mount tracking as some mounts require this extra step.

These mounts can be susceptible to imbalance in the altitude axis so make sure that the telescope, with camera attached, is balanced correctly by adding weight to the front of the telescope if required.

▲ The Celestron CPC 925 is capable of keeping a planet in view for minutes

Steve's top tip

What is an eyepiece's field of view?

The body of an eyepiece is normally marked with two important pieces of information; the focal length in millimetres and the apparent field of view (AFOV) in degrees (°). The AFOV figure is not, however, the field of view that you will observe through a telescope as this is dependent on the magnification of the telescope-eyepiece combination. The true field of view identifies how many degrees of the sky are covered by the diameter of the circular view observed through the telescope, and can be determined by this calculation:

$$\text{TRUE FIELD OF VIEW} = \frac{\text{APPARENT FIELD OF VIEW}}{\text{MAGNIFICATION}}$$

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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EDITORIAL
Editor Chris Bramley
Art Editor Steve Marsh
Production Editor Neil McKim
News Editor Elizabeth Pearson
Staff Writer Iain Todd
Reviews Editor Paul Money

CONTRIBUTORS
Paul G Abel, Danielle Adams, Kathrin Altwegg, Shaoni Bhattacharya, Guy Consolmagno, Lewis Dartnell, Glenn Dawes, Ben Evans, Will Gater, Pete Lawrence, Sandra Kropa, Martin Lewis, Chris Lintott, Mark Parrish, Steve Richards, Steve Sayers, Steve Tonkin, Jane Williamson, Emily Winterburn

ADVERTISING SALES
Advertising Manager Sam Jones +44 (0)117 300 8145, sam.jones@immediate.co.uk
Inserts Laurence Robertson +353 (0)87 690 2208

PRODUCTION
Production Director Sarah Powell
Production Coordinator Derrick Andrews
Ad Services Manager Paul Thornton
Ad Coordinator Florence Lott
Ad Designer Parvin Sepehr
Reprographics Tony Hunt, Chris Sutch

LICENSING
Director of Licensing and Syndication Tim Hudson
International Partners' Manager Anna Genevier

MARKETING
Head of Circulation Rob Brock
Head of Marketing Jacky Perales-Morris
Marketing Executive Craig Ramsay
Press and PR Manager Emma Cooney

PUBLISHING & MANAGEMENT
Publisher Jemima Dixon
Managing Director Andy Healy
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Chair, Editorial Review Boards Nicholas Brett
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UK Publishing Coordinator Eva Abramik
UK.Publishing@bbc.com; www.bbcstudios.com

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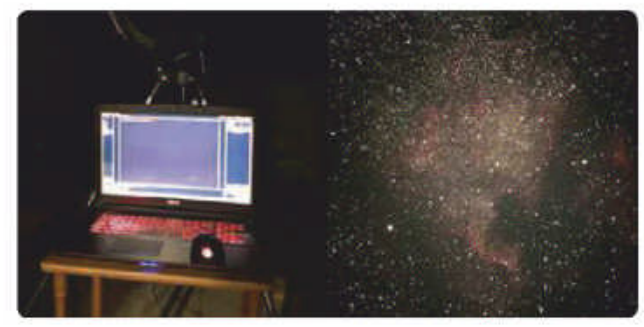
Tweets

Phill
@BHM_2345 • 26 Sep
Started taking photos again, here is NGC 700 13x 40 secs taken with a 60D stock, astronomic CLS filter, sigma 70-300 lens on a 4SE mount. Still learning how to stack & edit in photoshop @skyatnightmag



The role of science

▸ I found Darryl Quantz's article ('Astronomers, your planet needs you!', November) interesting and informative. However, I am disturbed that he states in regard to "...the role of humanity in global warming..." that "...as scientists, astronomers need to reiterate the strong findings on climate change from the scientific community". This conflicts with the professional behaviour of scientists, who normally working within their own specialism, examine all findings and evidence prior to forming their conclusions.

There is a plethora of evidence both supporting and denying anthropogenic causes of climate change, some from eminent, appropriately qualified scientists and, unfortunately, some from opinionated 'experts'. Astronomers, due to their comprehension of the influences of solar and planetary activity over the short term on our weather and the long term on our climate, are capable of reaching some of their own decisions on the intricate and numerous causes of climate change.

Scientists, just like Galileo, should be permitted to make up their own minds without exhortation. They must stand up for either their own or other scientists' beliefs even when these challenge or oppose the current scientific or religious wisdom and beliefs. I trust you will appreciate that this letter neither agrees with nor seeks to deny the effects of anthropogenic activity on climate change, but challenges a misconception of the role of scientists.

Margaret Dale, via email

Correction

In our feature 'Fireworks of the Night Sky' (November), we said The Witch Head Nebula was 2.5° northeast of Rigel, when it is northwest of the star

SOCIETY IN FOCUS

In 2019 Bromsgrove Astronomical Society had another fantastic year of stargazing and outreach events for members and newcomers alike. From 27-29 June the annual Bromsgrove Beer and Cider Festival took the 50th anniversary of the Apollo 11 moonlanding as its theme and the society was invited to set up a display and give stargazing advice. Some 3,000 thirsty punters attended, making it one of the society's biggest outreach events ever.

We were also invited to participate in this year's Shirejam, the Hereford and Worcester County Scout Jamboree held every July in Malvern. Many Scout packs took up our offer of the chance to observe the night sky through scopes to help with their astronomer activity badges. At the other end of the age spectrum, we gave talks to U3A groups in January and September.

In June we visited the Jodrell Bank Observatory for a tour of its telescopes and science centre (pictured, right), while our annual star party took place in

September. On 7 October we held an open evening, welcoming the public to come and view the night sky through our scopes.

Bromsgrove Astronomical Society membership ranges from newcomers to experienced observers, with a current headcount of 60. We meet at Bromsgrove Rugby Club on the first and third Monday of the month for an observing night and an evening of talks, respectively. Here's to more successful stargazing in 2020!

David Jones, Outreach Team, Bromsgrove Astronomical Society
▸ www.broms-astro.org.uk

Our pick of the best events from around the UK

WHAT'S ON

Songs by Starlight

The Observatory Science Centre, Hailsham, 30 November, 5.30pm

Come along for Christmas songs sung by a local choir, mince pies and mulled wine, and the chance to look through the observatory's telescopes. Booking is essential – call 01323 832731. Entry is £12 (adults) and £8 (children).

www.the-observatory.org/events

Christmas Star Party

The Downs, Bristol, 3 December, 7pm

Wrap up and join the Bristol Astronomical Society and Explorer Dome for a night of festive stargazing and storytelling, spotting the main winter constellations. Entry is £7.50 (adult) and £4 (child), includes a hot drink and a star-shaped cookie!

bit.ly/bristolstarparty

The Christmas Star

Seething Observatory, Norfolk, 6 & 7 December, 8pm

Mark Thompson from BBC *Stargazing Live* gives a talk on the astronomical events that may lie behind the story of the star that led the wise men to Bethlehem. Entry costs £3 (non-member adults), £1.50 (under 16s).

www.norwichastro.org.uk/events

Lincolnshire Star Party

Wood Centre, Market Rasen, 7 December, 7.30pm

Join expert astronomer Richard Darn to tour the winter constellations, find colourful doubles and clusters, and learn how to photograph the Moon's features. With mulled wine, juice and mince pies. Entry costs £13.50 (adults) and £8 (children).

bit.ly/lincolnshirestarparty

THE OBSERVATORY SCIENCE CENTRE, LIFE SCIENCE CENTRE X 3/SARAH DEAN 2017

PICK OF THE MONTH

▲ **Space is the place: see the biggest planetarium in the north of England and much more**

New Space Zone opens

Life Science Centre, Times Square, Newcastle upon Tyne, open daily at 10am (Sun 11am)

There's a shot in the arm for space fans in the North East with the opening of the new Space Zone at the Life Science Centre in the heart of Newcastle upon Tyne.

It features the biggest planetarium in the north of England, which plays host to a variety of shows, including presenter-led night-sky tours. There's also plenty of hands-on fun, like operating a Mars rover from mission control and launching your own rocket. Visitors can touch Moon rock and climb inside a mock-up of part of the International Space Station.

The Life Science Centre likes to encourage curious minds, so there are friendly Science Explainers on hand to answer your questions.

The cost of entry to the Space Zone is included with entry to the Life Science Centre, with no additional charge for special shows. Family entry is £31, adults are £12, children aged 5 to 17 are £7.50, and it's free for 4 year-olds and under.

Visit the website for a programme of space-themed events in the new Zone.

life.org.uk/events/space-zone

Santa Science

Ranmoor Parish Centre, Sheffield, 10 December, 7.45pm

Join Sheffield Astronomical Society as it takes a light-hearted look at the physics of Santa, presented by Dr Susan Cartwright. Entry is £3 (non members); £1 (under 18s).

www.sheffieldastro.org.uk

The Sun

Science and Industry Museum, Manchester, ends 5 January

A last chance to catch this exhibition looking at our relationship with our closest star using family-friendly exhibits. Entry is £8 (adults) and kids go free.

bit.ly/scienceandindustrymuseum

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The amateur astronomer's forum

FIELD OF VIEW

Stargazing on the right side of the law

Keeping safe at night time in remote locations is a priority for astronomers. **Robin Scagell** offers some tips on what to do and, importantly, what to avoid

Robin Scagell is the vice president of the Society for Popular Astronomy and a prolific author of guidebooks on observing the night sky, including *Philip's Complete Guide to Stargazing*

Few of us have the ideal observing location, and finding somewhere to observe can be a challenge. The simplest solution is to make the most of where you are: the Sun, Moon and bright planets shine through even the worst light pollution, and some leading planetary observers achieve brilliant results from urban locations. Skilled astrophotographers can now get impressive deep-sky images even in city skies by using narrowband filters.

But there comes a point where you need darker skies. If you have a car, it might seem easy enough to head for a country area, but finding a good and safe spot can be tricky. A layby in a country lane is likely to have passing cars whose lights are a nuisance and whose occupants may stop and ask what you are up to, or worse. Country car parks are often frequented by people you'd rather not be involved with, particularly if you are equipped with telescopes, binoculars and cameras – not to put too fine a point on it!

However, the risks of lone observing in dark places can be more imagined than real. In my experience the most likely problem is that your observing time will be spent chatting to police officers grateful for an unusual diversion on a quiet night. But it might help to carry a copy of *Sky at Night Magazine* to help convince them of your story.

It's a good idea to carry out a daytime recce of a potential observing site, as drawbacks are not always obvious at night. The ideal location should have solid, level ground and be well away from habitation, as well as having an unobstructed, dark horizon. But if you are concerned about your safety, the best solution is to find a landowner who is happy to let you observe from their property. This is not always as simple as knocking on a nearby farmhouse door, as these days much of the land is owned by conglomerates and the adjacent farmhouses are private residences.

Campsites are also a possibility, though you'd need to find one where you can keep well away from others, both to allow you to get on with observing and to avoid disturbing the other guests. There are also star parties around the UK where you can observe in company, and some local astronomical societies organise observing weekends in dark-sky areas.

That said, there is a real need for purpose-designed observing areas, and our dark-sky parks should aim to provide these. A concrete hardstanding and a wind break against the prevailing wind, accessible but away from public roads, would be a boon to amateur astronomers.

Those without a car are limited to sites within easy reach of home. Here the options are very limited, as you will usually be in public areas. All you can do is to find spots which are not often frequented. Churchyards are worth a try, if the church is not floodlit. But wherever you choose, check with the owner of the site. They may say no or require unreasonable notice (which would be hard to arrange, given our weather), but if you're lucky you could get access to a secure site that you were unaware of.

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BBC Sky at Night MAGAZINE

12 SIGHTS OF CHRISTMAS

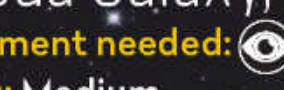
Vatican Observatory director **Brother Guy Consolmagno** 'unwraps' 12 deep-sky gifts for the festive season

The 12 nights around new Moon are the best time to hunt for deep-sky objects, those faint but elegant wisps of light that are so much fun to see with a small telescope. As it happens, this year there's a new Moon on Christmas night, which makes it a perfect time to try out your new telescope or eyepiece.

Here are a dozen of my favourite Christmas deep-sky objects, easily seen in an 8-inch (200mm) telescope around 10pm on 25 December. Most of them can also be observed with smaller telescopes, especially if the sky is good and dark. Some are particularly nice in binoculars, and a few can even be seen with the naked eye. For detailed directions on how to find them consult your favourite planetarium software, star atlas, or a good astronomy guide book.

Brother Guy Consolmagno is director of the Vatican Observatory. His book *Turn Left at Orion*, is a classic for beginner stargazers.

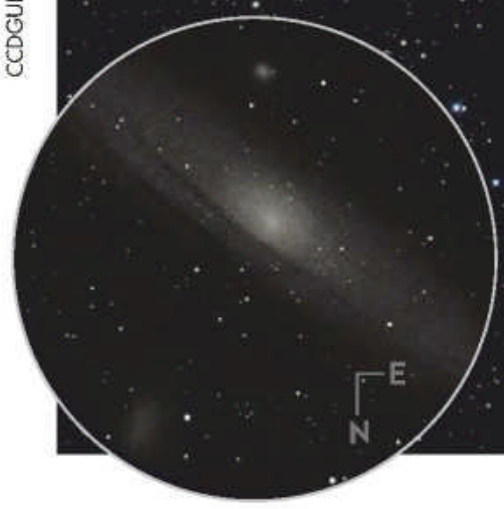
1. Andromeda Galaxy, M31

Minimum equipment needed: 

Difficulty rating: Medium

Our first object can be seen south of Cassiopeia with the unaided eye if you have a good dark sky. An easy smudge of light even in binoculars, a small telescope shows the core of this galaxy as a streak of faint light. The longer you look, the more of the streak you'll see, until it completely crosses your telescope's field of view. The galaxy is a nearly edge-on disc of around 300 billion stars spread over a diameter of 15,000 lightyears, some 2.5 million lightyears away. ►

▼ Eyepiece view: 8-inch telescope, 40x magnification



CEDIC TEAM/CHRISTOPH KALTSEIS/CCDGUIDE.COM, FRANZ KLAUSER/CCDGUIDE.COM, © MICHAEL VLASOV 2019 - DEEPSKYWATCH.COM X 2

2. Orion Nebula, M42

Minimum equipment needed:
Difficulty rating: Beginner

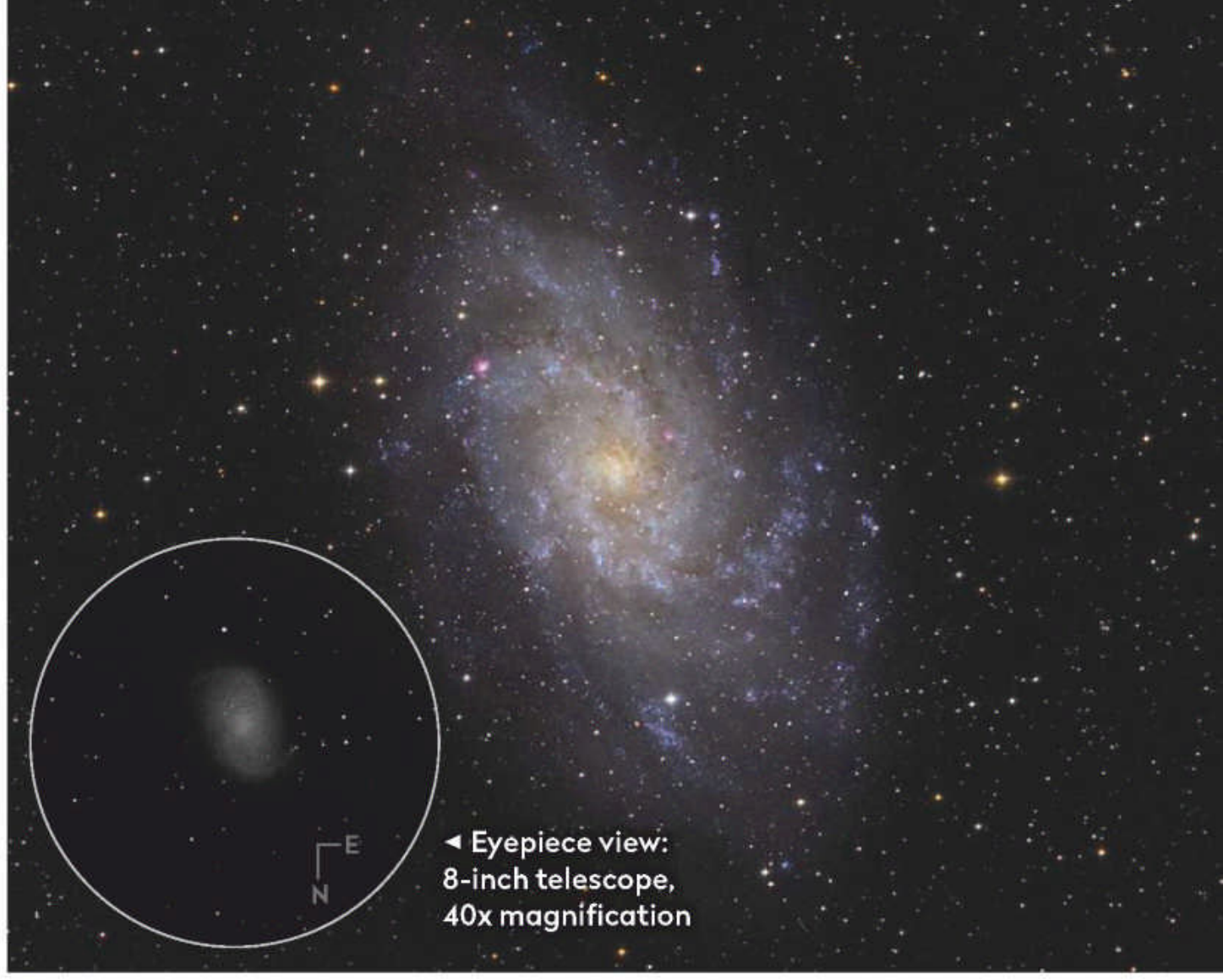
Visible even to the naked eye as the fuzzy spot in the sword hanging from Orion's Belt, our next object is lovely to look at through a pair of binoculars. With a dark sky and a bigger telescope, the Orion Nebula is stunning. Look for a faint greenish tinge in its colour, this is light emitted when the high energy radiation of newly born stars irradiates the atoms of oxygen in the surrounding cloud of gas and dust. This cloud itself, where thousands of young stars are being formed, is about 20 lightyears wide and located 1,350 lightyears away. ▸

◂ Eyepiece view: 8-inch telescope, 80x magnification

3. Triangulum Galaxy, M33 ▷

Minimum equipment needed: binoculars
Difficulty rating: Expert

Located south of Andromeda, this fainter galaxy will be hard to spot even in an 8-inch telescope if the night isn't perfectly dark. But if the night is just right, you can actually see it with binoculars as a ghostly disc of light. Unlike the Andromeda Galaxy, what we're seeing here is the full disc of this galaxy face-on. It's located about 3 million lightyears from us, and contains over 10 billion stars. The Andromeda and Triangulum galaxies, and our own Milky Way, are the three largest members of our local cluster of galaxies, imaginatively called 'The Local Group'.



◄ Eyepiece view: 8-inch telescope, 40x magnification

► Eyepiece view: 10-inch telescope, 77x magnification

◁ 4. Double Cluster in Perseus, NGC 869 & 884

Minimum equipment needed: binoculars
Difficulty rating: Beginner

This is a fun pair of open clusters of stars. You can spot them with binoculars south and east of Cassiopeia, and they're an easy spot in an 8-inch telescope, but they look their best in a small telescope around three inches (75mm) in diameter. In the view then, the light of the fainter members makes an eerie glow behind the brighter stars of the cluster. These clusters are stars born together out of a nebula like Orion's; look for a scattering of red stars among them, which were once the largest and brightest of the original stars, now evolved into red giants.

5. Galaxies M81 & M82 ▷

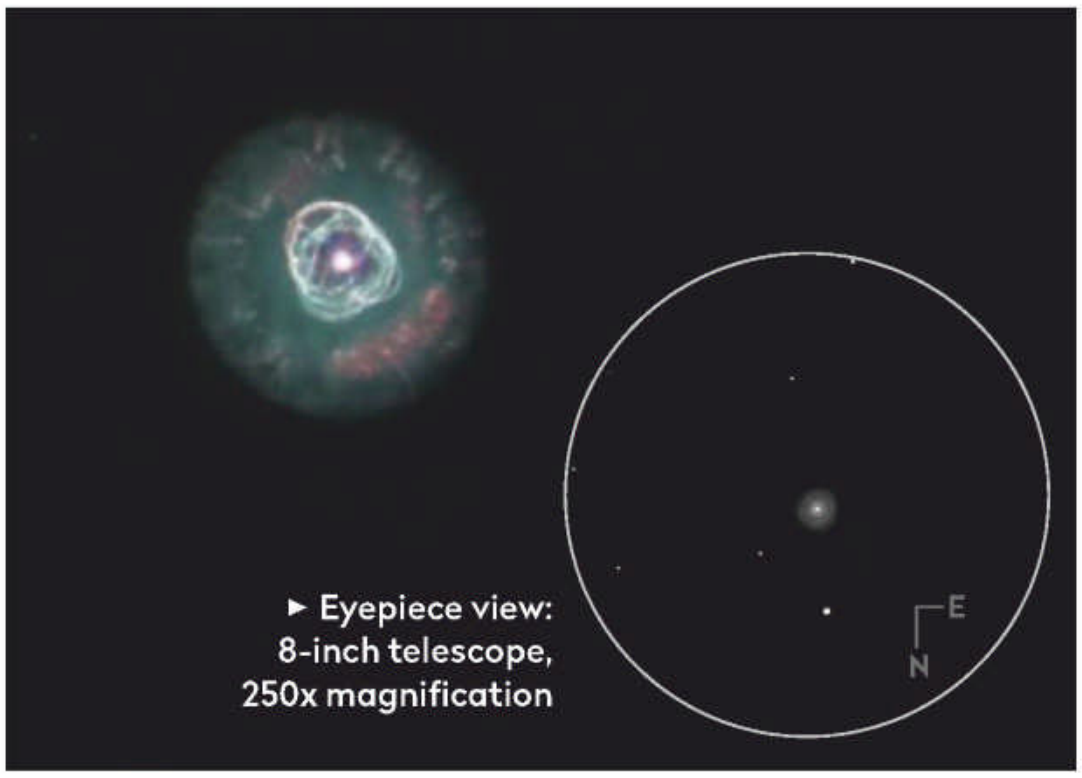
Minimum equipment needed: telescope
Difficulty rating: Expert

Next find Ursa Major, northwest of the Plough's blade (or the Big Dipper's bowl): it's here that there are a pair of galaxies visible together in a small telescope's field of view. They're hard to find – you'll need a dark sky and no Moon or city lights – but it's a thrill once you do catch them. Look for a thin line of light (M82) and, to its south, an oval of light (M81). The two are located about 12 million lightyears from us and less than a million lightyears apart; they apparently passed close to each other about 200 million years ago, which may have twisted M82 into the odd shape we see today.

▼ Eyepiece view: 8-inch telescope, 40x magnification

The 12 Sights of Christmas
25 December 2019, 10pm

URSA MAJOR
M81 & M82
5
CAMELOPARDALIS
CEPHEUS
CASSIOPEIA
LACERTA
4
Double Cluster
LYNX
LEO MINOR
PERSEUS
ANDROMEDA
AURIGA
Capella
M31
1
PEGASUS
GEMINI
Castor
Pollux
3
M33
TRIANGULUM
7
M35
8
Pleiades
6
NGC 2392
M1
9
ARIES
LEO
Aldebaran
TAURUS
CANIS MINOR
ORION
CANCER
PISCES
Betelgeuse
Procyon
HYDRA
2
M42
Keid
10
MONOCEROS
Rigel
12
CETUS
LEPUS
AQUARIUS
Sirius
ERIDANUS
CANIS MAJOR
M79
11
Festive view: use this chart to locate the 12 objects over the Christmas period
SE
S
SW



► Eyepiece view: 8-inch telescope, 250x magnification

▽ 7. Open Cluster M35

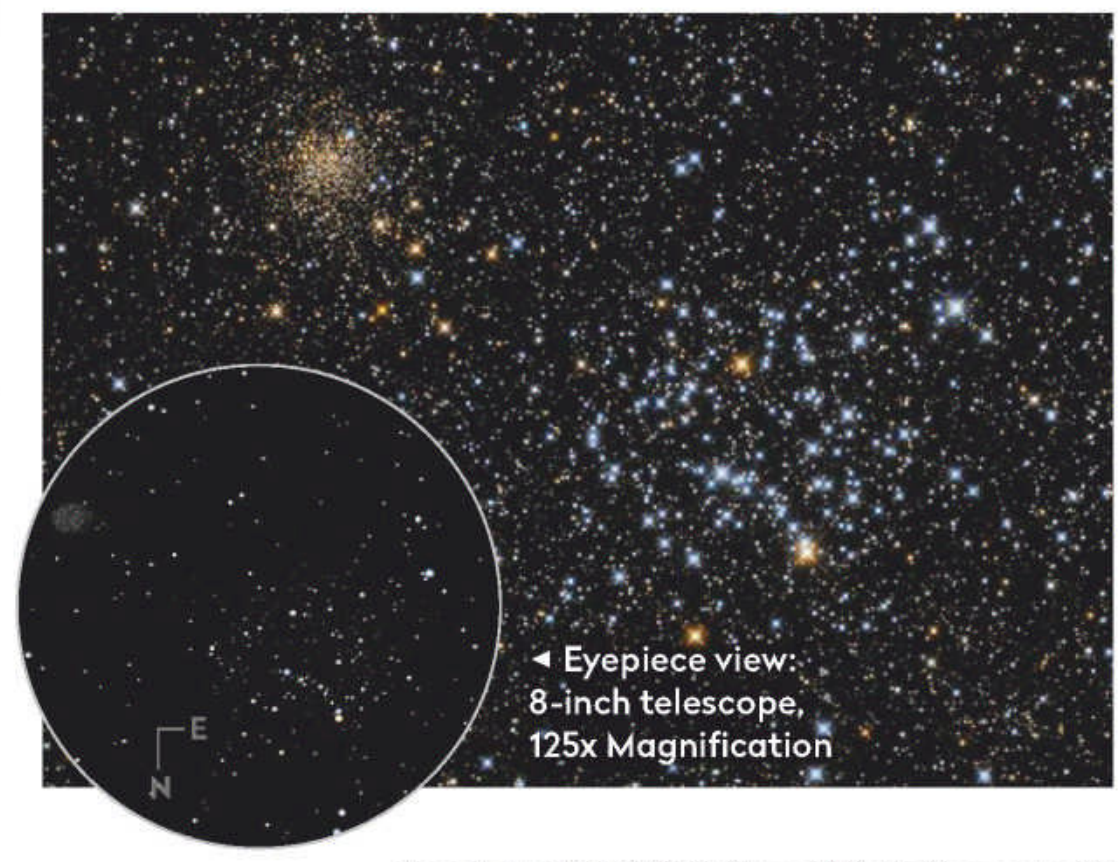
Minimum equipment needed:
Difficulty rating: Beginner

Located near Castor's right foot in Gemini, our next object at first looks only like about half a dozen stars; but let your eye relax and eventually more and more of the fainter stars begin to reveal themselves. It's a fun effect, especially in binoculars or a small telescope. All told the stars cover a region some 30 lightyears wide, located about 3,000 lightyears away from us. For a bonus, with a bigger telescope look for a fuzzy patch of light in the same field of view, just to the southwest of M35. That is NGC 2158; another, more distant open cluster. ►

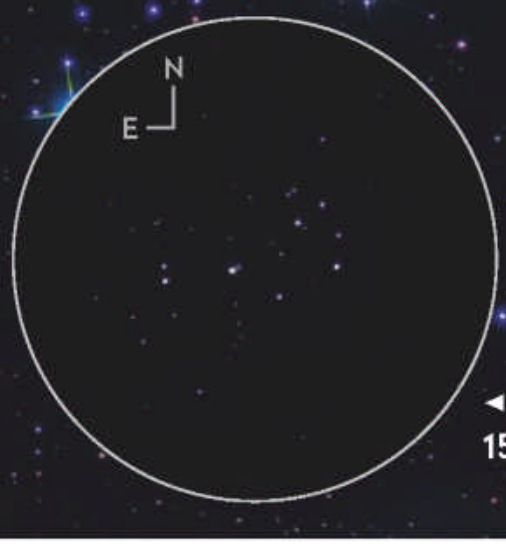
△ 6. Clown Face Nebula, NGC 2392

Minimum equipment needed:
Difficulty rating: Expert

Also known as the Eskimo Nebula, NGC 2392 in the constellation of Gemini is perhaps the nicest planetary nebula in the winter sky. In your scope you'll see what seems at first to be a pair of stars of similar brightness, but higher magnifications show one of those 'stars' to be a fuzzy blue-green disc, with just a hint of the internal structure that gives it its fanciful name. See if you can spot its central star. The nebula is called a 'planetary' only because it looks like a planet in a small telescope; in fact, it's a pulse of gas emitted from the central star in the final stages of its evolution.



◄ Eyepiece view: 8-inch telescope, 125x Magnification

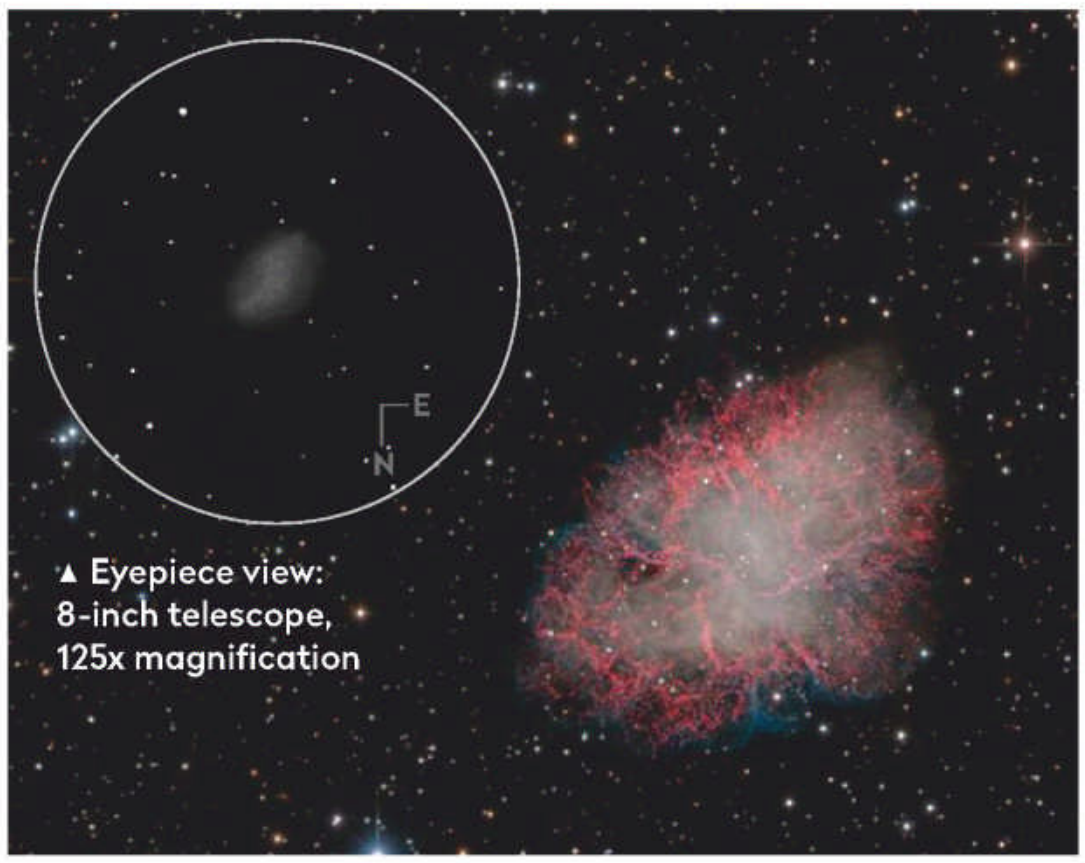


◄ Eyepiece view:
15x70 binoculars

△ 8. The Pleiades, M45

Minimum equipment needed: 
Difficulty rating: Beginner

This famous open cluster is easy to see even with the naked eye, northwest of Orion. Also known as the Seven Sisters, this collection of stars looks great in binoculars, which will show half a dozen brighter members in a dipper shape among another dozen fainter ones. With higher magnification you'll see more. In fact, there are thousands of stars in the cluster, 400 lightyears from us, born out of a nebula that once was like Orion's. A bigger telescope and dark skies can show you the faint wisp of a nebula just south of the 'bowl' of stars. However, if you're seeing nebulosity around every star, your lens is probably covered in dew!



▲ Eyepiece view:
8-inch telescope,
125x magnification

△ 9. Crab Nebula, M1

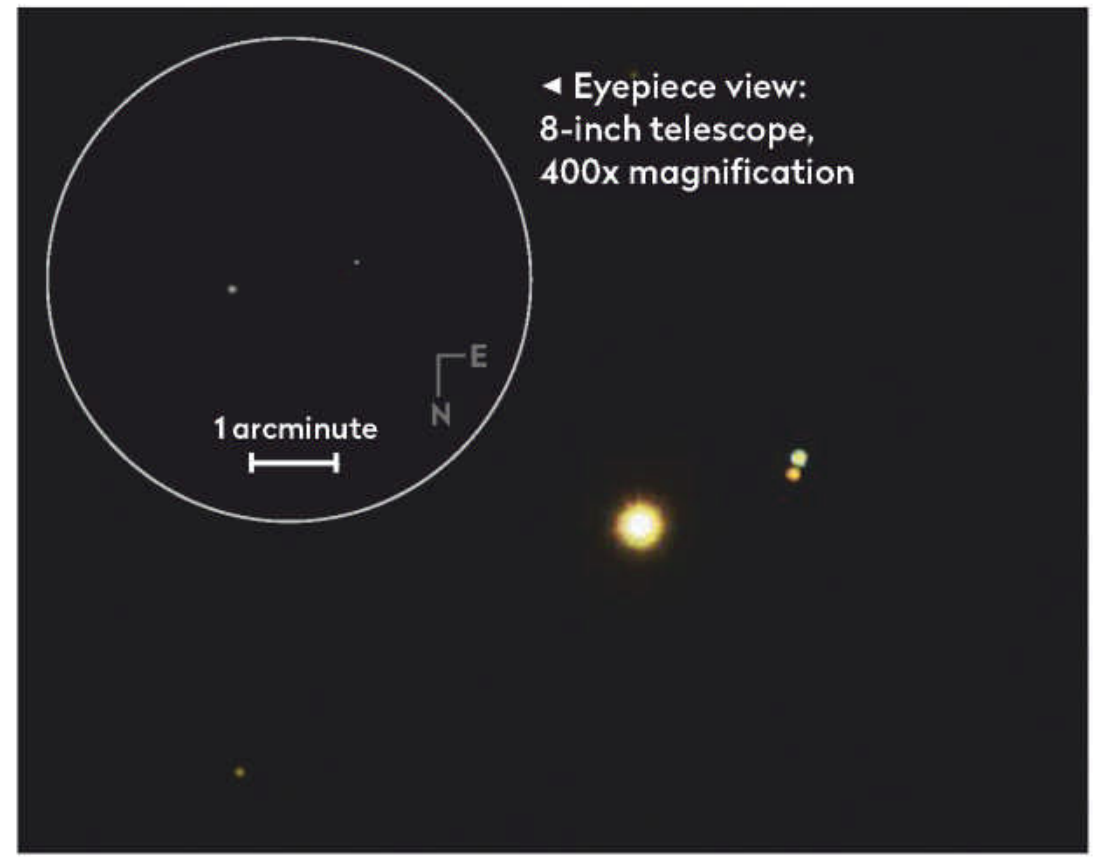
Minimum equipment needed: 
Difficulty rating: Expert

In Taurus, north of Orion, lies this object, famous for being the remnant of a supernova that exploded in AD 1054. Its brilliance made it visible even in daytime, but before long it faded from sight... until, that is, John Bevis found a cloud of light there with his telescope in 1731. In 1758, Charles Messier designated it as M1, his catalogue's first entry. In 1844 William Parsons sketched it, and thought it looked like a crab, hence its name. Today it's about half as bright as it was in Messier's era; you'll want a dark sky to find it.

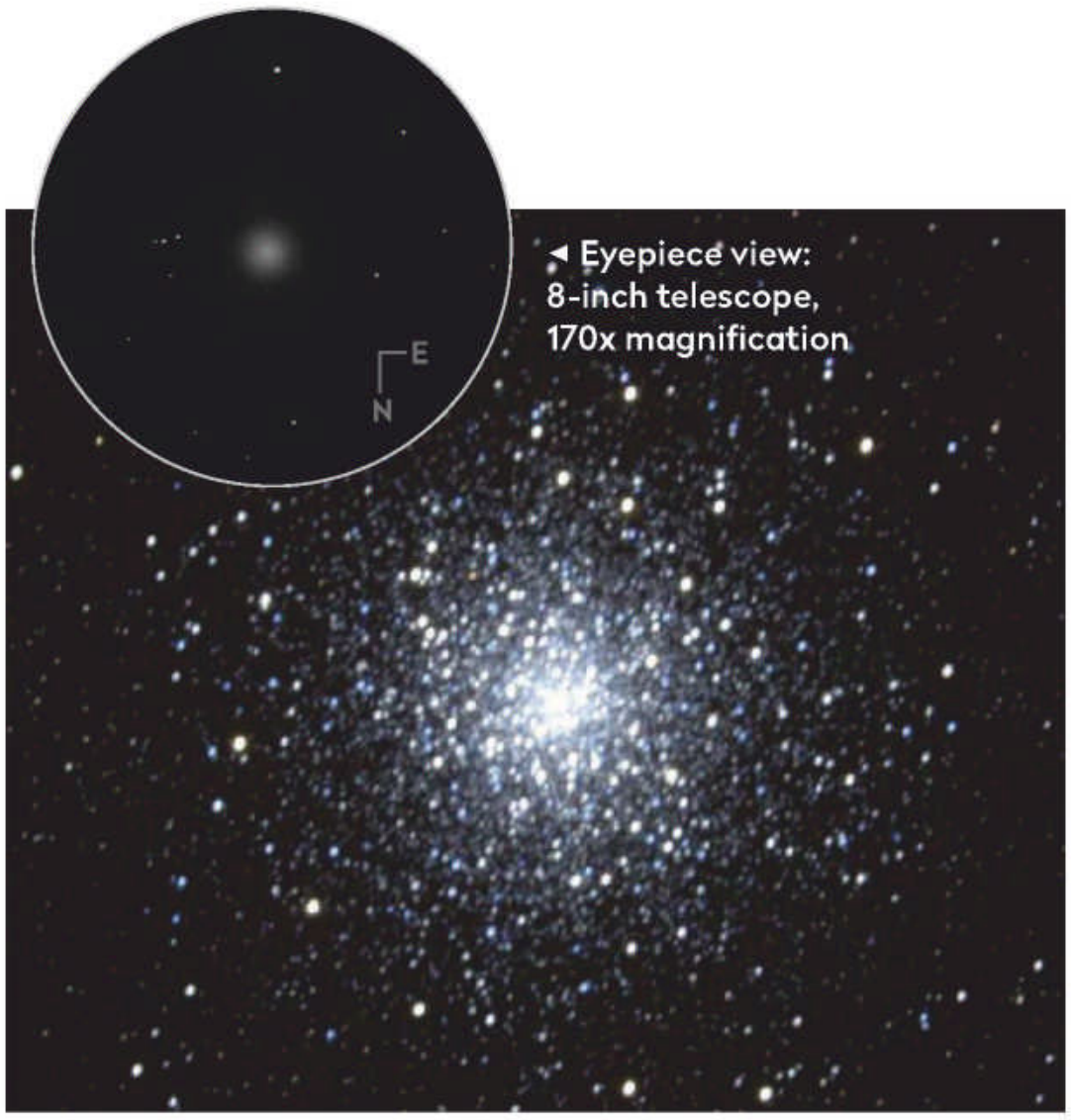
▽ 10. Keid, 40 Eridani

Minimum equipment needed: 
Difficulty rating: Medium

This triple star system, located in the obscure constellation of Eridanus southwest of Orion, is a serious challenge to find, with few bright stars nearby. So why bother? For one thing, its companion – a 10th magnitude star to its east – is the easiest white dwarf star that you can see in a small telescope. And that white dwarf is, itself, a double: look for a slightly fainter star to its northwest. One more fun fact: according to Gene Roddenberry, the creator of *Star Trek*, Keid is the sun of Mr Spock's home planet, Vulcan.



◄ Eyepiece view:
8-inch telescope,
400x magnification



△ 11. Globular cluster M79

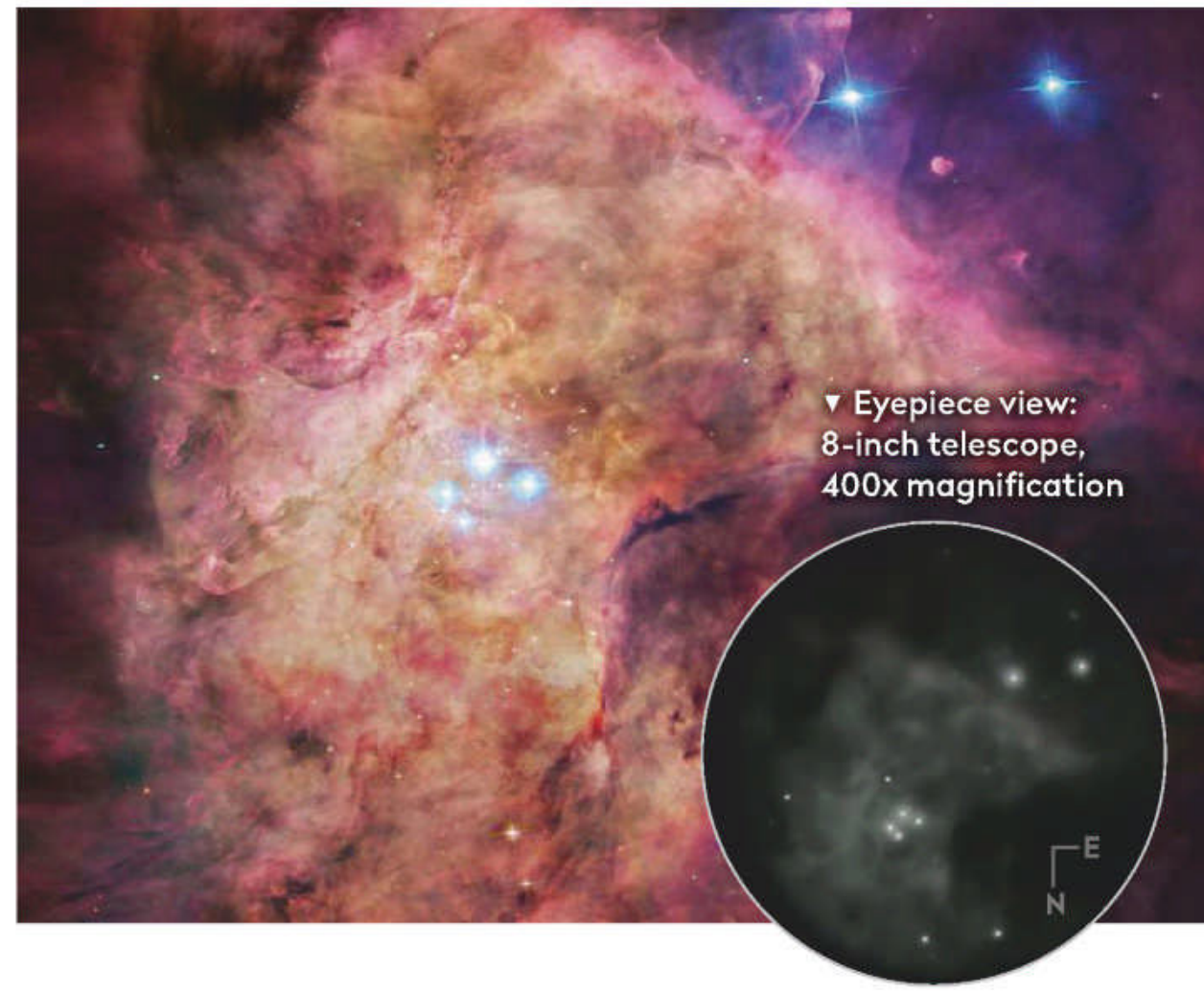
Minimum equipment needed:
Difficulty rating: Medium

This globular cluster in Lepus, due south of Orion, is the only one visible at this time – the autumn globulars M15 and M2 set soon after sunset. Look for it when Orion is at its highest; from Britain it rarely gets more than 10° above the horizon. But even a small telescope reveals it to be very pretty ball of light. This cluster of 150,000 stars sits 40,000 lightyears away from us, towards the outer edge of our Galaxy. Some astronomers have proposed that it isn't really a globular cluster at all, but an interloping dwarf spherical galaxy that has (relatively) recently merged into our Milky Way.

▽ 12. The Trapezium, Theta-1

Minimum equipment needed:
Difficulty rating: Medium

Our last target is a great excuse to return to the Orion Nebula (No. 2 on our list). The Trapezium is a set of four newly formed stars in the heart of the Nebula; use your highest magnification to pick them out. Star A is the westernmost; the north one is B; the southernmost and brightest is C; and the one furthest to the east is D. With a larger telescope you can spot two more stars, E (north of A) and F (east of C). William Herschel, observing in the late 1700s, did not see E or F; but his son John did, around 1820. Did they only just appear during that interval?



What was the Christmas star?

Uncertainty surrounds the star that led the three wise men to Bethlehem


Star of wonder? Astronomers are still guessing which star guided the Magi

Every Christmas, astronomers get asked about the star that the Magi followed. What was it? Probably more different answers have been proposed than there are astronomers – a Google search will reveal nearly 30 million hits!

The simple answer is, nobody knows for sure. How could we? The only place it is mentioned is in 11 verses of St Matthew's Gospel and nowhere else. It might have been a pious tale, or some supernatural event. But that hasn't stopped astronomers, going back at least to Kepler, from testing different theories.

Some favourites are probably unlikely. Comets are most likely out: they were portents of doom, not of the birth of a king. Any nearby supernova 2,000 years ago should have left a remnant visible today, like the Crab Nebula. Conjunctions of planets are a popular solution, but it's hard to fit all the details of the story in St Matthew.

In *The Star of Bethlehem* (1999), Michael Molnar notes that all of the planets known to the ancients rose in conjunction with the Sun in April of 6 BC. The timing is right; it would be a sign in the east known only to astrologers, because the planets were hidden in sunlight; and it's consistent as a portent of a king's birth.

Was that really the 'star'? Maybe. But until we can interview St Matthew, we'll never know for sure.

SPACE IN 2020

Elizabeth Pearson looks ahead to the missions heading out into our Solar System this year

As 2020 marks the start of a new decade, it also marks a new era for space. In the coming years, both China and the US are taking their human spaceflight programmes to the next level, with both agencies setting their sights firmly on the Moon. The ultimate goal for this human exploration is to send people to the surface of Mars in the 2030s. That's not to say the Red Planet is being neglected until then. A fleet of robotic explorers is being prepared to fly in 2020, ready to join the many spacecraft already at Mars and explore the planet for many years to come.

However, the road to the stars is not an easy one, particularly if you're left stranded on Earth without a lift. Both NASA and China's heavy launch rockets – the Space Launch System (SLS) and the Long March 5 respectively – have been delayed for years. The Long March 5 was taken off China's launch roster in 2017, when one fell into the ocean shortly after launch. The rocket is due to return to flight later this month, but if things don't go according to plan, several key missions could be delayed. Over in the US, the official line is that the SLS will be up and running by mid-2020, but several comments from NASA administrator Jim Bridenstine referring to a 2021 launch date have sowed doubt.

However, even without these two vehicles, 2020 is shaping up to be a pretty major year for humanity's exploration of the Solar System. ▸

NASA/JPL-CALTECH, DOTTEDHIPPO/ISTOCK/GETTY IMAGES

Destination Mars: NASA's Mars 2020 rover mission is schedued to launch in July

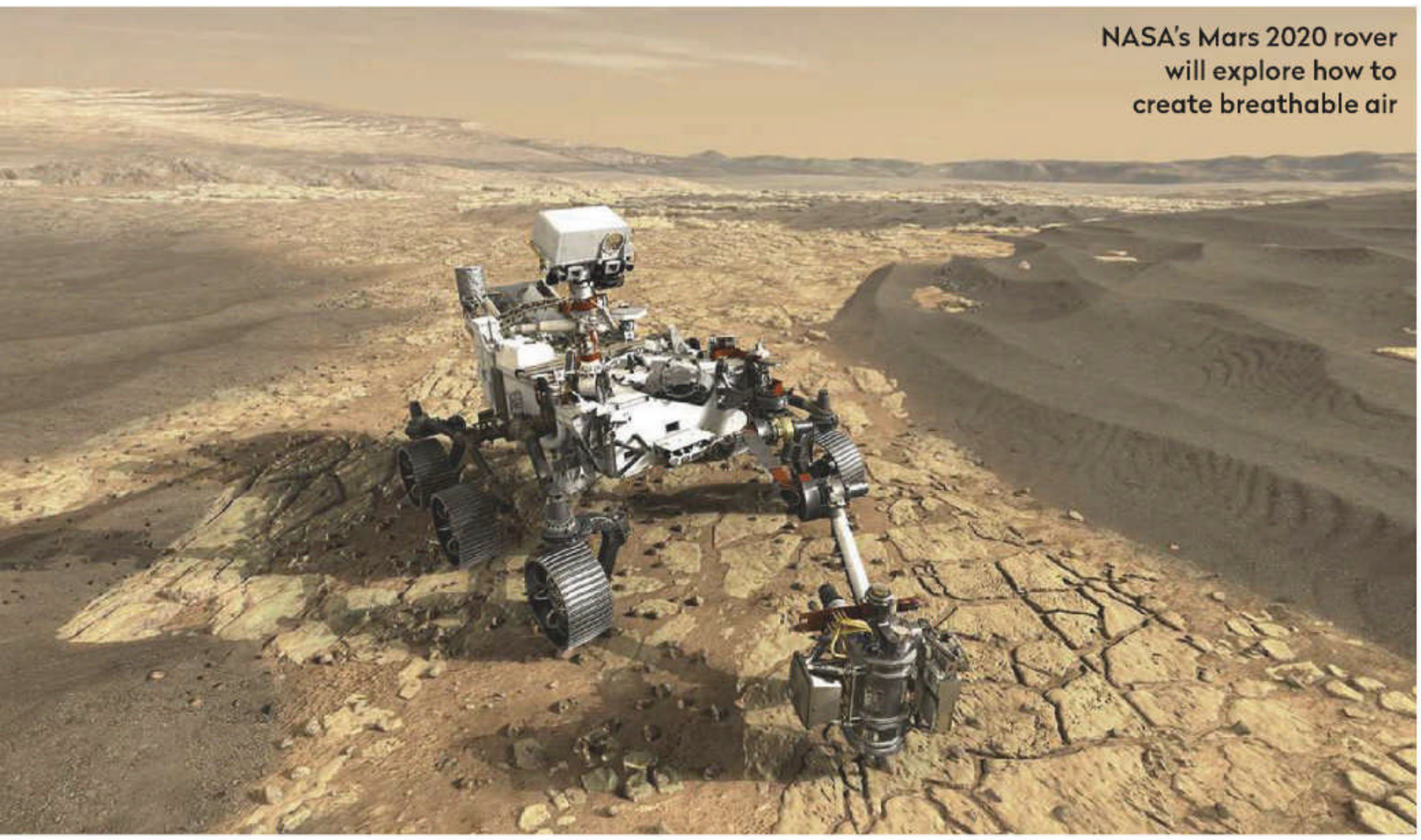
EARTH'S MARTIAN INVASION

July 2020 sees an event that only occurs once every 26 months, the Mars launch window. This year an armada of spacecraft are planning on making the trip to the Red Planet.

NASA is planning on adding another mission to its long list of Mars explorers with the Mars 2020 rover. However, rather than being a scientific mission in its own right, the rover will pave the way for future Martian exploration by both robots and humans.

The rover's main task is to collect samples from across Mars's surface. But instead of analysing them in an onboard laboratory, the rover will create caches for a future mission to collect and bring back to Earth. This return mission is currently being planned by both NASA and the European Space Agency (ESA), who are expected to commit to the return mission at the next ministerial meeting in late November 2019.

The Mars 2020 rover will also carry several technology demonstration experiments. One of these, the Mars OXygen In-situ resource utilization Experiment (MOXIE), will suck carbon dioxide in from the Martian air, then split it apart to create oxygen. The technology could one day be used to create rocket fuel and breathable air. Finally, the rover will carry the Mars Helicopter Scout, a drone-like probe that flies through the thin Martian atmosphere, reaching parts of the planet that rovers cannot.



NASA's Mars 2020 rover will explore how to create breathable air

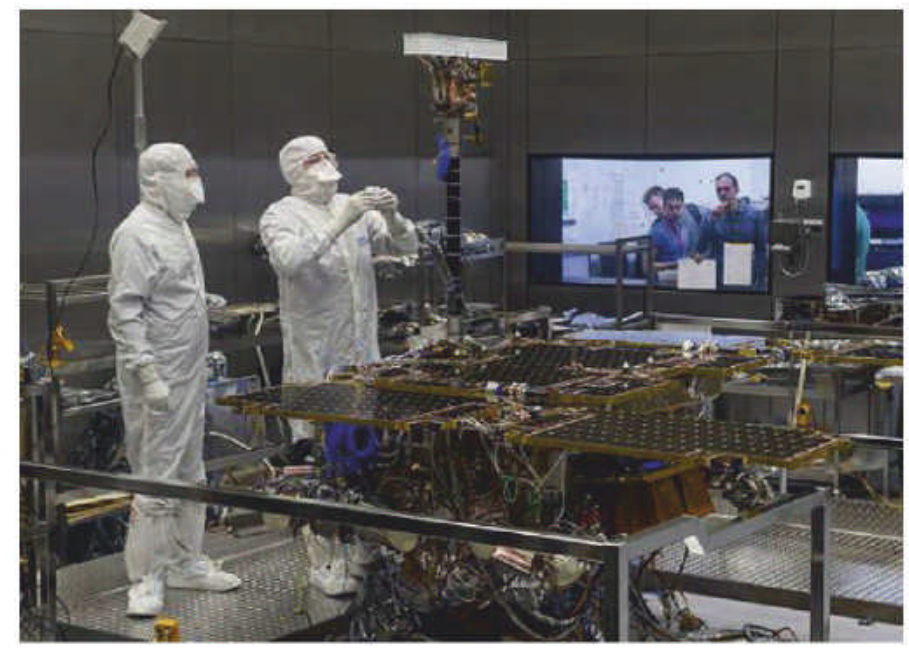
Signs of life

Joining NASA's rover will be the second half of ESA's ExoMars mission – the Rosalind Franklin rover.

"The main goal of the mission is to find evidence of past or present life," says Pietro Baglioni, the rover manager.

► **Left: the Mars Helicopter Scout will conduct tests in the Red Planet's atmosphere**

Far left: a Panoramic Camera system (PanCam) is fitted to ESA's Rosalind Franklin rover in August 2019



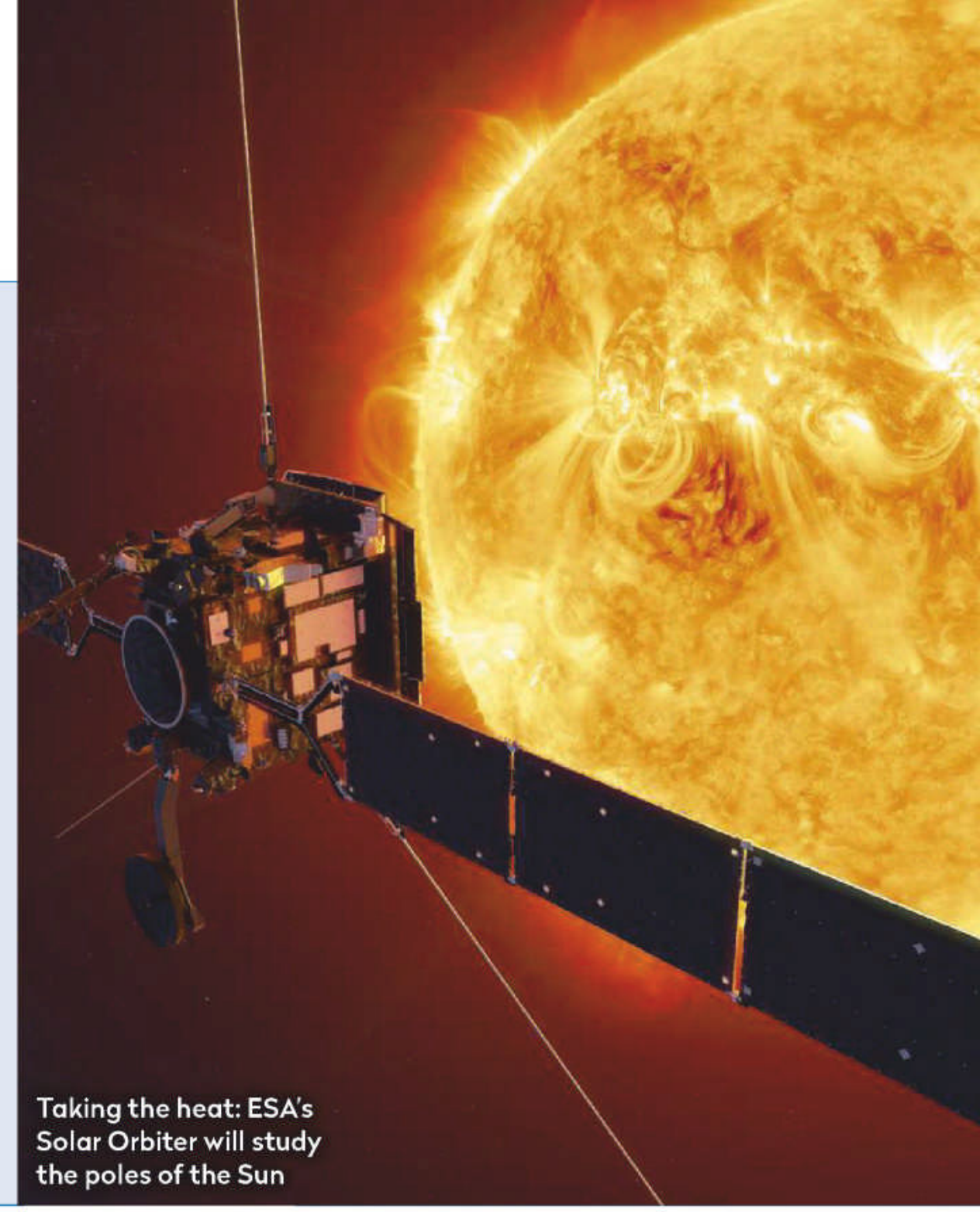
Sun seekers

Two solar spacecraft will soon be getting to know our star's atmosphere

In February 2020 ESA will launch the Solar Orbiter spacecraft. "The mission will explore the Sun and its connection to the plasma bubble that surrounds the Solar System we call the heliosphere," says Daniel Müller, project scientist on Solar Orbiter. "The key to understanding this lies in the polar regions of the Sun, which can't be seen from the ecliptic. We will fly a trajectory that gradually raises the orbital plane to get a good view of the poles."

The spacecraft's orbit will pass just 0.28 times the Earth Sun distance (42 million km) away from the solar surface, before swinging out towards Venus.

Meanwhile, the Indian Space Research Organisation (ISRO) is planning another solar mission, Aditya, which is currently due to fly in April. The spacecraft will look at the Sun's corona, as well as its ultraviolet radiation and the solar wind, both of which have an effect on Earth's climate and atmosphere.



Taking the heat: ESA's Solar Orbiter will study the poles of the Sun

However, as cosmic radiation has likely irradiated any life signs near the surface, the rover will have to dig in. "ExoMars will be the first rover equipped with a drill capable of penetrating to 2m, where there is more chance of finding something scientifically interesting."

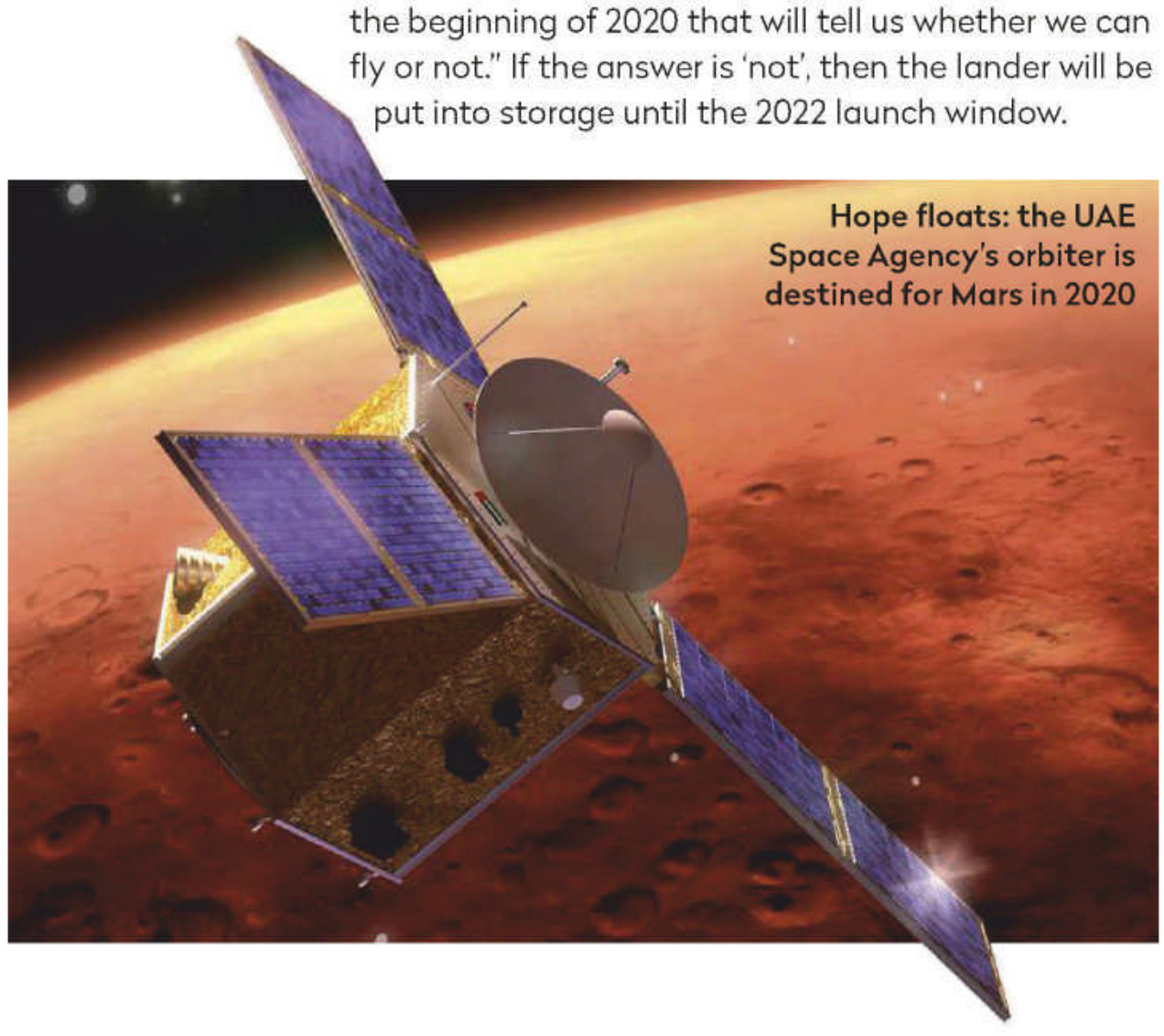
However, while the rover is ready, the landing system is not. When the first half of ExoMars – the Trace Gas Orbiter (TGO) – arrived at Mars in 2017, it dropped off a test lander, Schiaparelli, only for it to crash. While the cause of Schiaparelli's demise has been fixed, there are still other issues with the 2020 lander.

"We have experienced difficulties with the qualification of the parachute systems of the descent module," says Baglioni. "There are tests at the beginning of 2020 that will tell us whether we can fly or not." If the answer is 'not', then the lander will be put into storage until the 2022 launch window.

Joining these two will be a Chinese rover. Not much is known about the mission – China is secretive about its space efforts – but the nation has made no effort to hide the fact that it wishes to explore Mars. The rover will travel alongside an orbiter, and together they will study the planet's geology and atmosphere. Things seem on track, but the launch requires a Long March 5 rocket. Any delay with the launch vehicle could leave the rover with a 26-month wait.

Finally, the United Arab Emirates aims to launch its Hope orbiter, which will study Mars's atmosphere. The UAE Space Agency was only set up in 2014, and Hope is its first planetary space mission – a first step of an ambitious plan to build a colony on Mars by 2117.

Mars is already a busy place, with the Curiosity rover and several orbiters currently exploring the planet, but things will only get busier when the latest wave of Martian invaders arrives in 2021. ▸



Hope floats: the UAE Space Agency's orbiter is destined for Mars in 2020

ESA still hasn't cleared the Rosalind Franklin's parachute for landing

NASA/JPL/MSSS, NASA/JPL-CALTECH X 2, ESA/ATG MEDIALAB X 2, AIRBUS/M.ALEXANDER, MOHAMMED BIN RASHID SPACE CENTRE

HUMAN SPACEFLIGHT

The next decade is shaping up to be a landmark era for human space travel with missions to the Moon, space tourism flights and a new space station all set to start operations in the next 10 years.

In 2020, both SpaceX and Boeing are set to carry their first crew to the ISS as part of NASA's Commercial Crew Development programme. The project was set up in 2010 after the cancellation of the Space Shuttle, commissioning private companies to build and operate crew-capable spacecraft to and from the ISS.

Ready for launch: SpaceX's resuable Starship is set for a 2020 test flight

The first crewed test flight, each lasting only a few days, of both SpaceX's Crew Dragon and Boeing's Starliner are due to happen in the first quarter of 2020. As long as these flights don't show up any problems, the spacecraft will be then pressed into full operation in the following months.

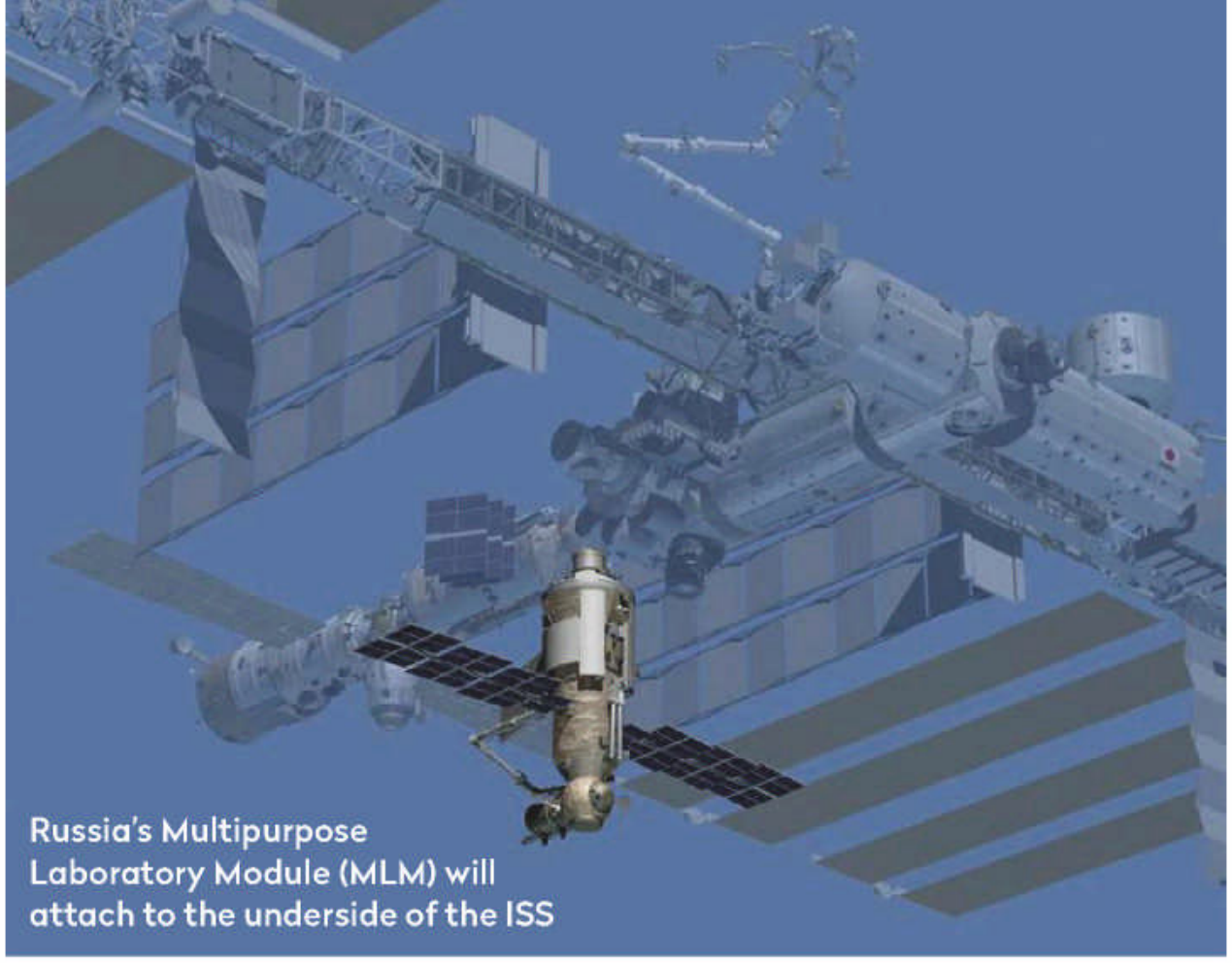
Elsewhere in the private sector, on 28 September 2019 SpaceX CEO Elon Musk announced that the first prototype of his new space vehicle Starship – a reusable spacecraft that will become SpaceX's main vehicle – will have its first test flight in early 2020, with potential crewed flights later in the year. Meanwhile, 2020 could be the year space tourism finally takes off, with both Virgin Galactic and Blue Origin tentatively stating they hope to start flying passengers by the end of the year.

Return to the Moon

With private enterprise taking over low-Earth orbit, NASA itself is concentrating on getting humans further out into the Solar System, starting with the Moon. The first test phase of this project, Artemis-1, is currently slated for a mid-2020 launch and will involve the first uncrewed test flight of NASA's crew capsule, Orion. The plan is to fly Orion around the Moon and back, but the mission requires the use of the SLS, which may not be ready in time.

Another human spaceflight mission that might be left on the ground awaiting a ride is the Chinese space station. The nation had hoped to use the

NASA aims to fly its unmanned Orion capsule around the Moon



Russia's Multipurpose Laboratory Module (MLM) will attach to the underside of the ISS

India is hoping to test its Gaganyaan crewed capsule at the end of 2020

ISS as a launchpad for sending its own taikonauts (Chinese for astronauts) towards the Moon and beyond, but a 2011 US law bans the two nations from working together, forcing China to work on its own space station. The first module of a permanent orbital facility is now due to fly in mid-2020, provided the Long March 5 is ready to carry it.

Russian developments

One mission that might get off the ground, however, is the latest expansion to the ISS from the Russian space agency, Roscosmos. The new module – a joint research hub, sleeping quarters and storage space known as the Multipurpose Laboratory Module (MLM) or Nauka – has been planned since before the main station even flew. However, its construction has been beset with problems. In 2014, its exterior plumbing had to be replaced following a leak, then three years later metal dust was found in the fuel tanks meaning they also needed to be changed. Now all fixed up, Nauka is scheduled to fly to the ISS in June 2020.

Elsewhere in the world, India is on the way to becoming the fourth nation capable of launching humans into space. The Indian Space Research Organisation (IRSO) is in the final stages of developing its Gaganyaan crewed capsules, with the first uncrewed test flights due at the end of 2020.

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

There and back again

Robotic sample return missions are growing increasingly commonplace

There's only so much scientific equipment you can put on a spacecraft. To really get to know a space rock, you have to bring a piece back to Earth.

Two asteroid investigating spacecraft are already hard at work. The first, Japan's Hayabusa2, arrived at asteroid Ryugu in June 2018. The spacecraft has already taken two rock samples and is due to head home in late 2019, arriving back in December 2020. Once safely recovered, its cosmic cargo will be sent off to the world's premier laboratories for close study.

Meanwhile, NASA's OSIRIS REx is taking its time at asteroid Bennu. OSIRIS REx has been mapping the asteroid since December 2018 to find the perfect landing spot. In mid 2020 it will touch down then harvest dust by blasting the surface with nitrogen gas. The spacecraft is due to leave Bennu in March 2021, reaching Earth in 2023.

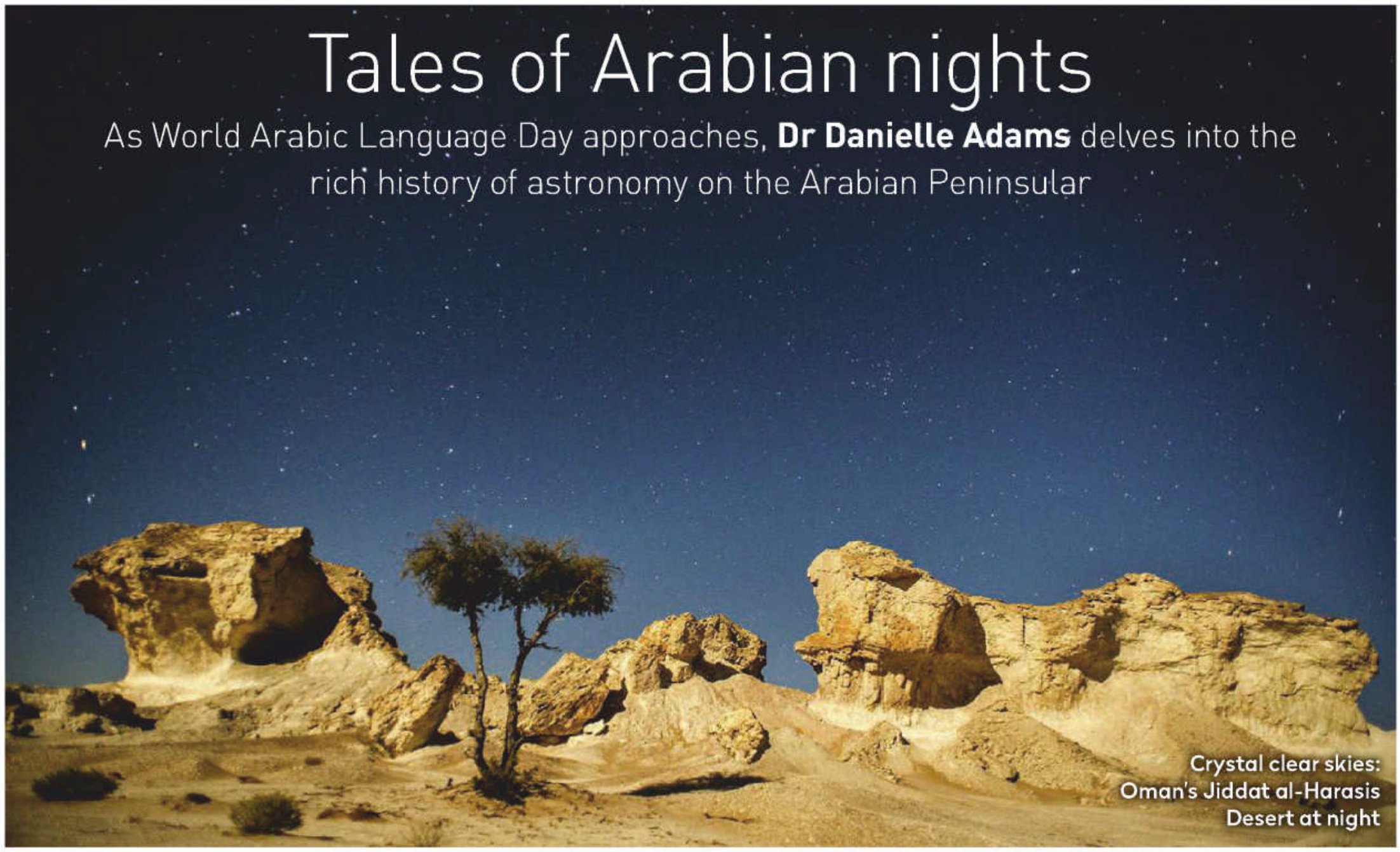
Meanwhile, the China National Space Administration (CNSA) is planning to launch its own sample return mission in 2020, this time to the Moon. The Chang'e 5 lander aims to return around 2kg of lunar material from up to 2m underground. However, launch is reliant on the uncertain future of the Long March 5 rocket.

OSIRIS-REx is scheduled to land on asteroid Bennu in 2020 to take samples

UNESCO World Arabic Language Day, December 18, 2019

Tales of Arabian nights

As World Arabic Language Day approaches, **Dr Danielle Adams** delves into the rich history of astronomy on the Arabian Peninsular



Crystal clear skies: Oman's Jiddat al-Harasis Desert at night

PHOTOSTAUD/ALAMY STOCK PHOTO, MARKUS BLAUENSTEINER/CEDIC TEAM/CCDGUIDE.COM, BERNHARD HUBL/ CCDGUIDE.COM, CHART BY PETE LAWRENCE

Our journey begins about 1,500 years ago when the earliest surviving Arabic poetry was orally recited by nomadic poets living in the Arabian Peninsula. At this time, the sky looked somewhat different, and not just because the Arabian Peninsula lies further south than Europe.

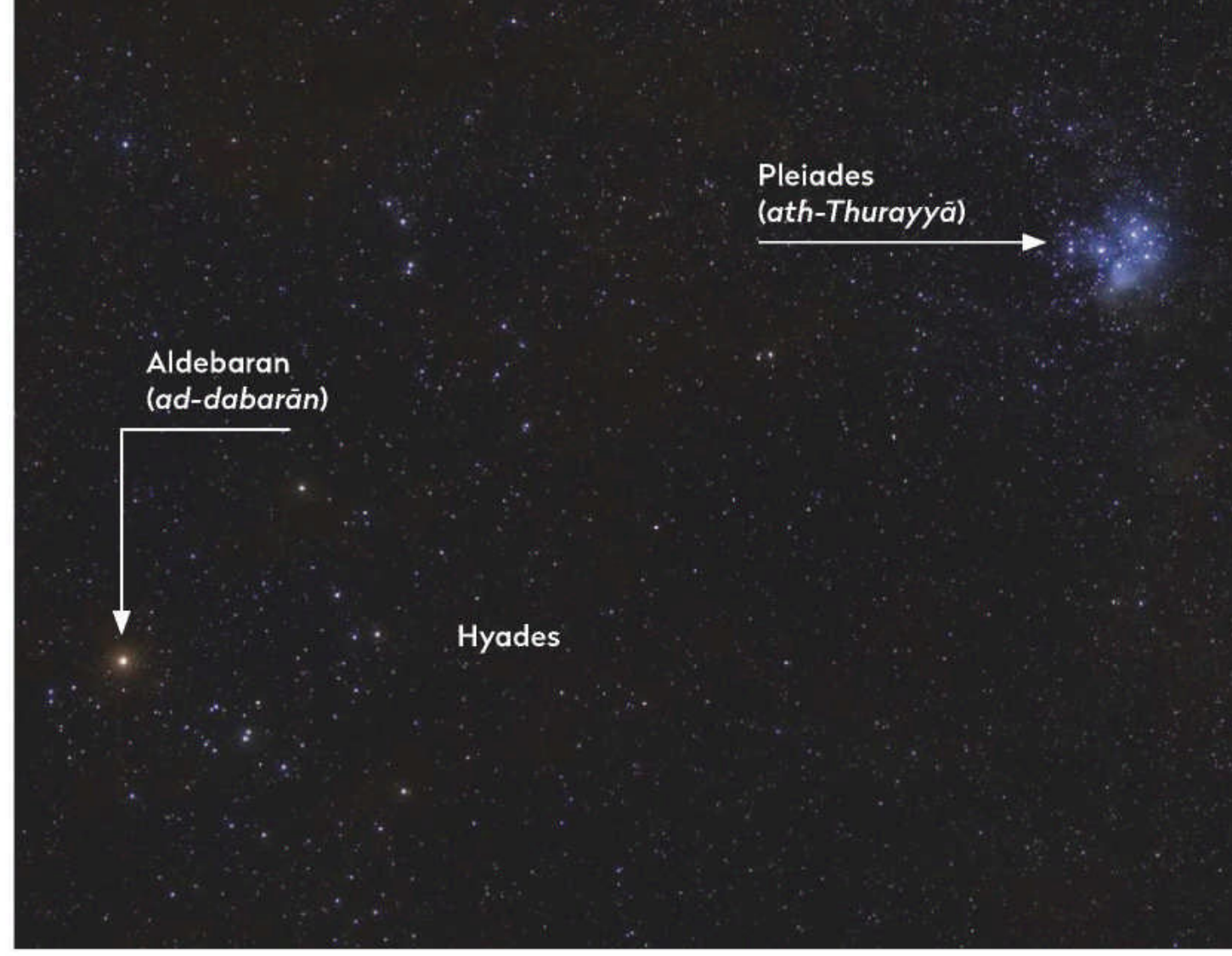
Earth wobbles as it rotates, causing its celestial poles to trace a circle across the sky over the course of almost 26,000 years, a process called precession of the equinoxes. As a result, pre-Islamic Arabian skies had no North Star. Instead, a stellar trio that danced around the North Celestial Pole marked the direction of north. One you may know as Polaris, our current North Star; in Arabia, this was called the Goat Kid (*al-jady* الجدي). The others were a pair of stars called the Two Wild Cow Calves (*al-farqadān* الفرقدان); today these are known as Pherkad from *al-farqadān* and Kochab from *kawkab*, meaning 'star'. These stars were used by camel caravan drivers for navigating the shifting sands of the desert.

Dr Danielle Adams is a cultural astronomer and deputy director at Lowell Observatory in Flagstaff, Arizona. For information on Arabian astronomy, visit her website **onesky.arizona.edu**

One story that has survived the ravages of time involves a brilliant red supergiant you may know as Aldebaran, the Follower (*ad-dabarān* الدبران). Just ahead of the Follower is the famed Pleiades star cluster, which was known in Arabia as Thuraya (*ath-Thurayyā* الثريا). Thuraya was in love with the Follower, but the Impeder (*al-'ayyūq* العيوق, the star Capella) prevented them from getting together. Now the Follower forever chases *ath-Thurayyā* across the sky as the Impeder watches them from high above.

Celestial bodies

As *ath-Thurayyā* was so celebrated in Arabia, it was often mentioned as 'the Star' (*an-najm* النجم, indicating a single star or small asterism). Over time it gained two arms, one of which extends into modern-day Cetus, while the other passes through Perseus to a five-fingered hand represented by the stars of Cassiopeia. Several modern star names point to the storied arms of *ath-Thurayyā* (*kaff ath-Thurayyā*, كف الثريا), including Caph from kaff, meaning 'hand', Mirfak (*al-mirfaq*, المرفق) from *mirfaq*, meaning 'elbow' and Menkib (*al-mankib*, المنكب) from *mankib* for 'shoulder'.



► Lovestruck: in Arabian stories *ad-dabarān* (Aldebaran) follows *ath-Thurayyā* (the Pleiades) across the sky

The motions of the stars were watched closely in Arabia, as their positions at specific times of the night indicated seasonal changes. "When the Star rises at nightfall, the herdsman earnestly seeks a cloth wrap", was a common saying pointing to the cold weather that arrived when *ath-Thurayyā* rose in the east as the Sun set in the west.

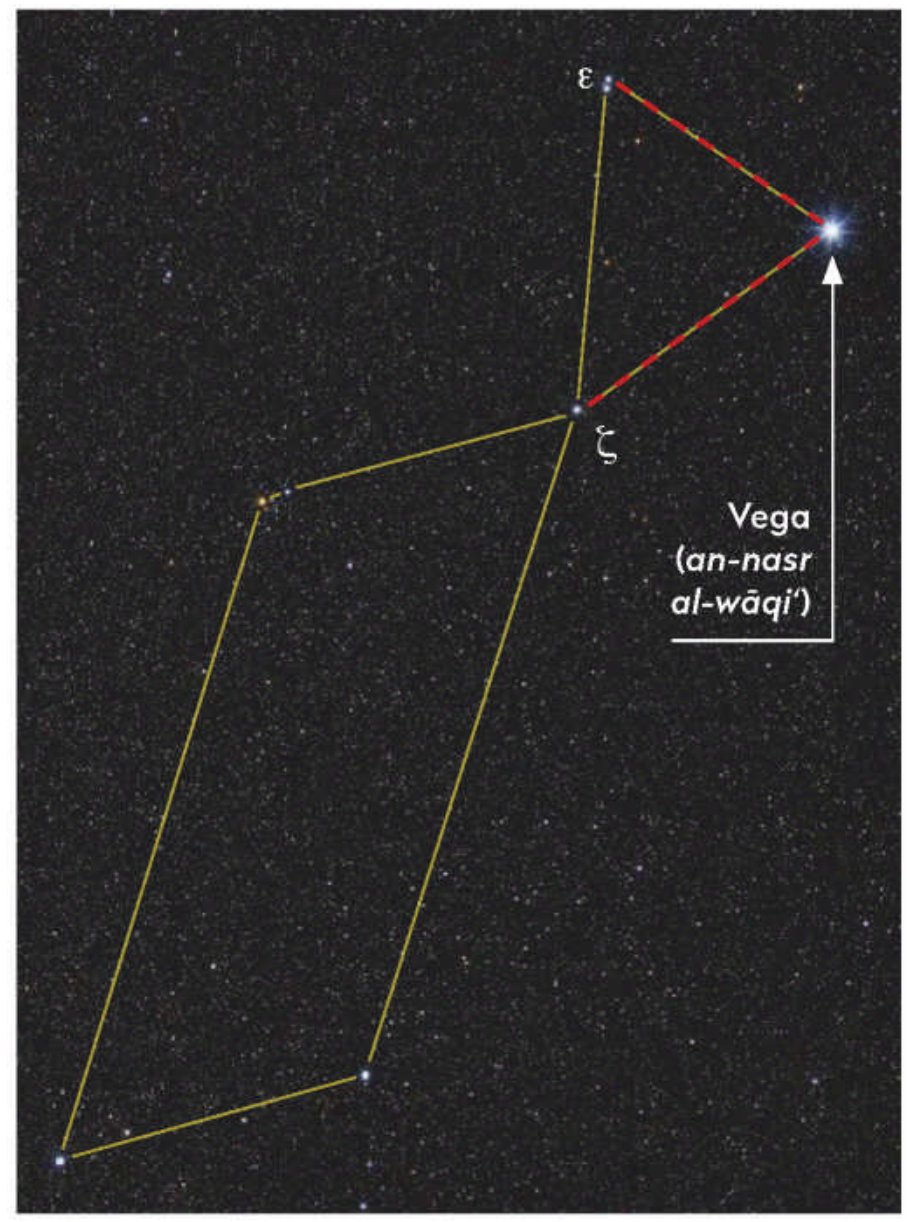
Flying high

More often it was the setting of stars at the end of the night that predicted seasonal changes. Autumn rains began at the dawn setting of two stars known as the Two Vultures (*an-nasrān*, النسران). One of these two stars you may know as Vega, its name derived from its Arabic name, The Alighting Vulture (*an-nasr al-wāqi'* النسر الواقع). This vulture was imagined as having its wings stretched back as it prepared to land, because it forms a small V-shape with the two nearby stars Epsilon (ε) Lyrae and Zeta (ζ) Lyrae. The other vulture star is Altair, known as The Flying Vulture (*an-nasr aṭ-ṭā'ir* النسر الطائر), because its nearby stars form a straight line like the wings of a soaring bird.

After the development of Islam in 622 AD and its spread outside of Arabia, Greek constellations were eventually grafted into Islamic astronomy. For example, Deneb comes from the Arabic *dhanb ad-dajāja* ذنب الدجاجة, meaning "the Tail of the Fowl", which indicates the star's position in the tail of the Greek constellation of Cygnus the Swan.

Some Greek constellations were given indigenous Arabian star names used elsewhere. The four stars that comprise the modern Square of Pegasus were known well before 622 AD as the Well Bucket (*ad-dalw* الدلو), because they resembled the shape of a bucket formed from a leather pouch by crossing two sticks at its mouth. Later, the name *ad-dalw* was given to Greek Aquarius, the water bearer who holds a bucket. Today, if you ask an Arab friend which constellation *ad-dalw* is, they will point you to Aquarius, not Pegasus.

The modern night sky showcases the remains of cultural interactions that span millennia. When you look up at the night sky this month, consider World Arabic Language Day and the great heritage of Arabian astronomy that endures to this day.



▲ Touching down: in Lyra the star Vega forms a V-shape (shown here in red) with Epsilon (ε) and Zeta (ζ) which appear as the outstretched wings behind the 'Alighting Vulture'

FINDING ARABIAN STARS

All the targets in this article are visible in our December skies shortly after sunset

▶ Look north to find the Goat Kid (Polaris) and the Two Wild Cow Calves (Pherkad and Kochab) still dancing around the North Celestial Pole.

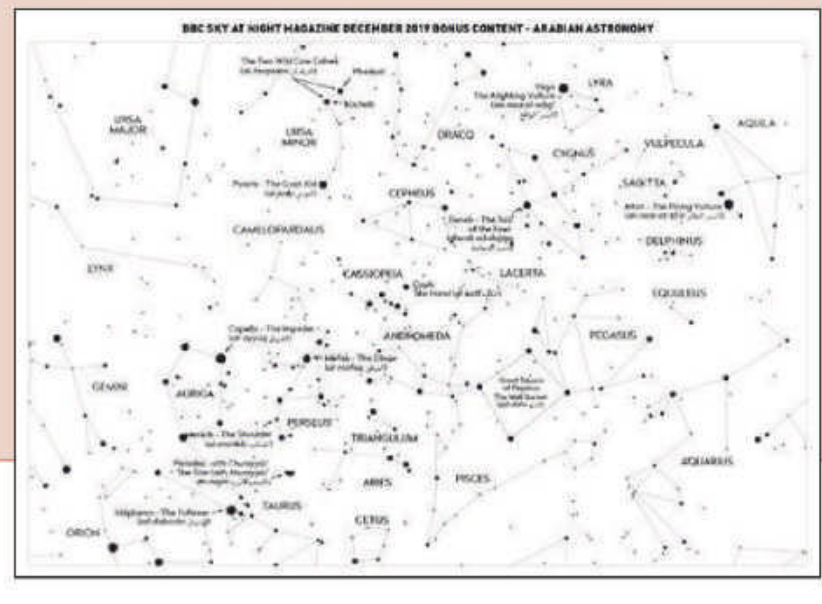
▶ Look above the eastern horizon to find brilliant red Aldebaran, the Follower, and the star cluster known as *ath Thurayyā*, or simply the Star (M45, The Pleiades). The Impeder (Capella) still watches from high above them.

▶ Look south to find the Well Bucket (The Great Square of Pegasus), both its indigenous Arabian stars in modern day Pegasus and its Islamic identification as Greek Aquarius.

▶ Look west to find the Two Vultures of Arabian astronomy (Vega and Altair), and Deneb, the tail of Greek Cygnus.

More **ONLINE**

Print out a chart with all of the stars mentioned in this feature. See page 5 for details.



BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

DECEMBER 2019

EVENING PLANETS

As Jupiter and Saturn bow out after sunset, they are joined by Venus as it dominates the twilight

INTERSTELLAR VISITOR

Follow the trail of comet 2I/Borisov

ANDROMEDA GALAXY

Observe our bright spiralling neighbour

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Catch the Geminid and Ursid meteor shower peaks
- Discover the wonders of Orion using binoculars
- Explore the lunar terrain of Doppelmayer

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

DECEMBER HIGHLIGHTS

Your guide to the night sky this month

Sunday
1 Mag. +1.0 Saturn, –3.8 Venus and –1.7 Jupiter appear close in the evening twilight.

Minor planet 97 Klotho reaches opposition at mag. +9.9 in the constellation of Eridanus. See page 53.

◀ Wednesday
4 The shadow of Jupiter's moon Callisto begins to transit the planet's disc in daylight from 12:40 UT. See page 47.

Wednesday
11 Mag. –3.8 Venus appears 1.8° south of mag. +0.9 Saturn low in the evening twilight after sunset.

Thursday
12 Mag. +1.7 Mars appears 16 arcseconds from mag. +2.8 Zubenelgenubi (Alpha (α) Librae. Spot the pairing low in the southeast from around 05:30 UT.

◀ Saturday
14 This morning and over the next few days, comet C/2017 T2 PanSTARRS will appear close to mag. +6.3 NGC 1545 and mag. +6.4 NGC 1528 in Perseus. The comet is predicted to be around mag. +10.2 at this time. See page 46.

Sunday
15 This morning's 90%-lit waning gibbous Moon will play host to the clair-obscur effect known as the Twin Spires of Messier, associated with the crater pair Messier and Messier A.

Thursday
19 Interstellar comet 2I/Borisov, the first such object identified, reaches its peak brightness today. This low morning object, in Hydra, requires a large telescope or photographic setup. Peak brightness is expected to be mag. +15.3. See page 46.

Friday ▶
20 Orion reaches its highest point in the sky, due south around midnight UT and the Moon has now moved out of the way. If you have access to dark skies, this is a great time to try to see or image Barnard's Loop. See page 55.

Sunday ▶
22 The Sun reaches its lowest position in the sky relative to the background stars today – the Northern Hemisphere's winter solstice.

The Ursid meteor shower (ZHR 10 meteors per hour) reaches its peak.

Family stargazing

Planet Venus is now easy to spot over in the southwest after sunset. It's good fun to see who can spot it first with just your eyes after the Sun has set. The position of this planet will only get better over coming months. Learning how to see it early on will tune young eyes to picking it out in the evening twilight. As the month progresses, Venus can be seen against a darker sky. In particular look out for the crescent Moon lying nearby on the evenings of 28 and 29 December. Get your young observers to draw or paint the scene if possible. www.bbc.co.uk/cbeebies/shows/stargazing

Monday
23 Mag. +1.6 Mars lies 3.2° from this morning's 9%-lit waning crescent Moon. See the pairing from 06:00 UT, low above the southeast horizon.

Friday
27 A challenging opportunity to catch a final view of Saturn before it's lost in twilight. This evening it's joined by a 2%-lit waxing crescent Moon, separated by 2.8°. Catch them low over the southwest horizon from 16:30 UT.

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Friday
6 The clair-obscur effect known as The Jewelled Handle is visible on the Moon this evening. This appears when the peaks of the Jura Mountains surrounding Sinus Iridum catch the light of the lunar dawn.

Saturday
7 This evening our Moonwatch target, Doppelmayer, is visible close to the terminator. See page 52.

◀ Friday
13 Tonight and into tomorrow morning sees the annual peak of the Geminid meteor shower. Unfortunately, a bright just past full Moon will spoil the show, being located within Gemini and up all night long.

Tuesday ▶
17 This month's Deep-Sky Tour (see page 56) takes a look at a favourite object for amateur astronomers, the Andromeda Galaxy, M31. It can be seen under moonless dark-sky conditions almost overhead, early evening from today.

Saturday
28 Mag. –3.9 Venus appears 4.8° from a 6%-lit waxing crescent Moon.

From the UK the Moon will appear below and right of Venus, low in the southwest at 17:30 UT.

Sunday
29 This evening the Moon, now at 12% illumination, will appear 6.9° left and slightly above Venus as seen from the UK. Look towards the southwest from 17:30 UT.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

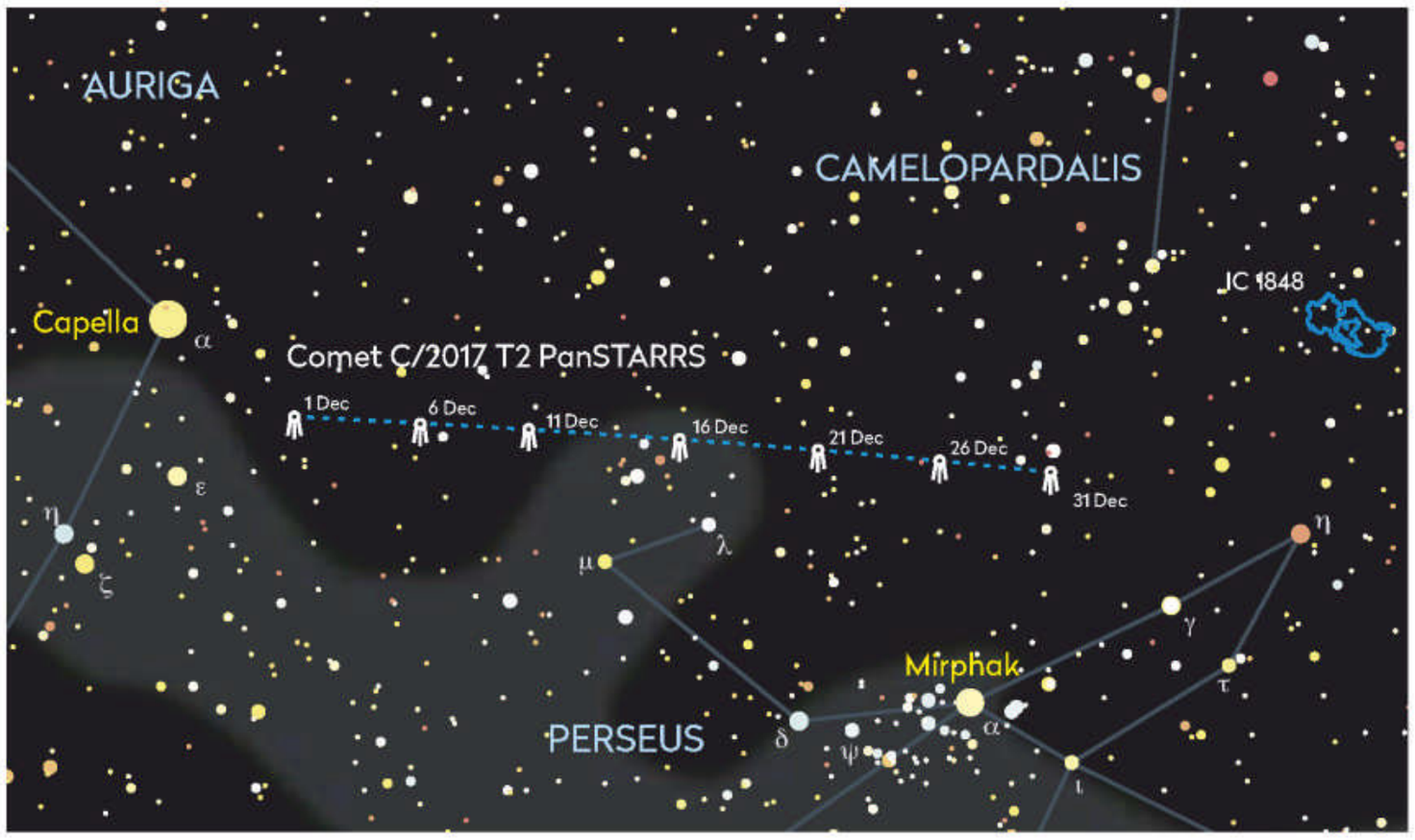
The three top sights to observe or image this month

DON'T MISS

Comets

C/2017 T2 PanSTARRS and 2I/Borisov

BEST TIME TO SEE: C/2017 T2 PanSTARRS – 1–9 Dec and 15–31 Dec; 2I/Borisov – all month. The Moon will interfere 12–22 Dec



▲ **Comet C/2017 T2 PanSTARRS will visit Auriga, Perseus and Camelopardalis this month**

We first mentioned comet C/2017 T2 PanSTARRS in September's issue. Its position in the sky is favourable from the UK, the comet being circumpolar for several more months. It was discovered in September 2017 and gained notoriety because a limited set of observations made as the comet was close to being hidden by the Sun left the door open for a range of peak magnitudes, the highest of which was in the naked-eye range.

Now with several months under our belt, has anything changed? The comet is still visible and will perform its closest approach to Earth on 29 December. Perihelion – the point in its orbit when it's closest to the Sun – isn't until 4 May 2020, the comet being at its brightest on 10 May. This is due to its increased activity as it gets closer to the Sun, the perihelion distance being 1.61 AU.

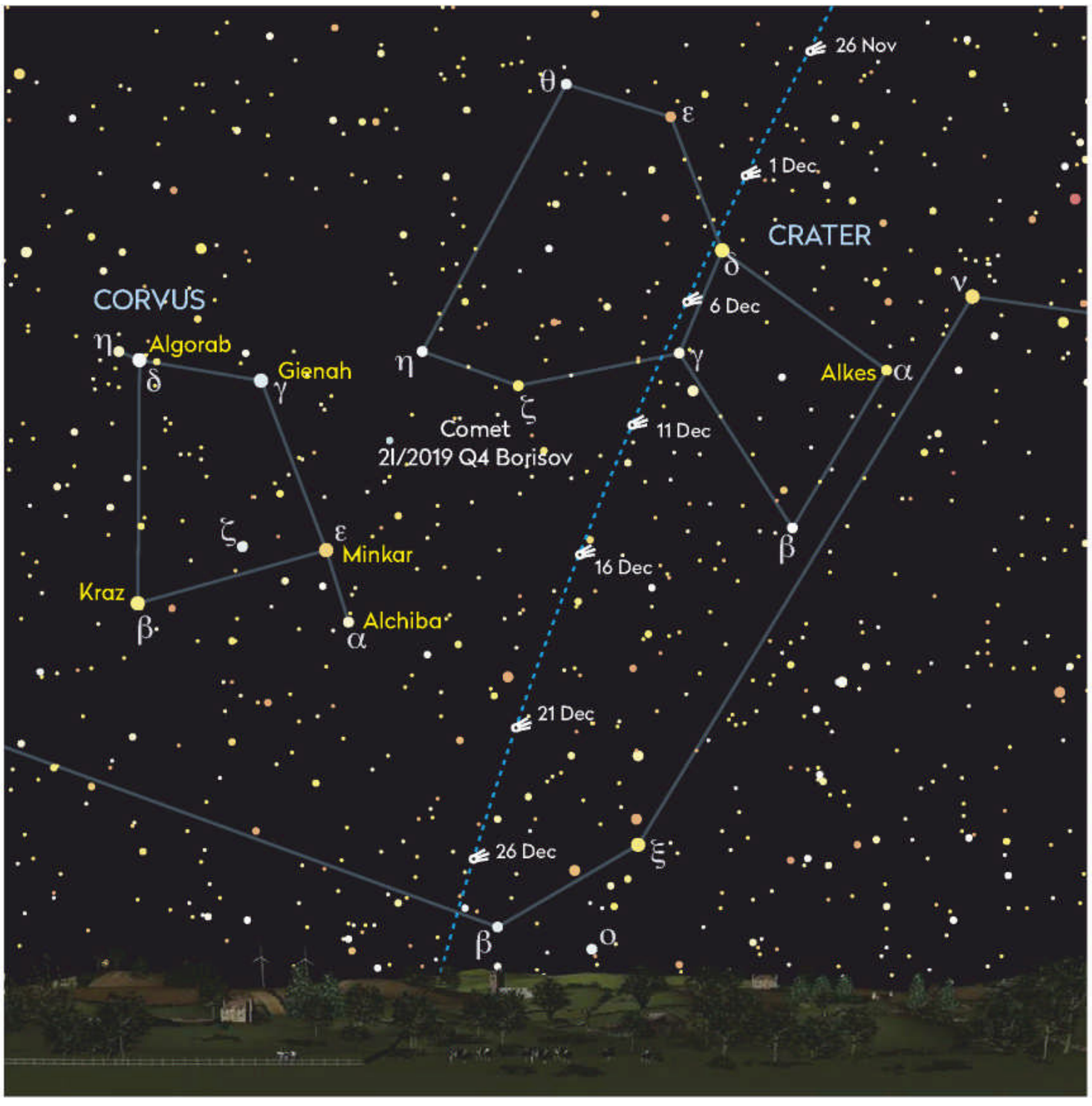
This month C/2017 T2 PanSTARRS starts its track in Auriga, not far from the star Capella (Alpha (α) Aurigae). It then passes through the northern region of Perseus, clips the southwest corner of Camelopardalis before technically returning to Perseus at the end of the month.

But what about that magnitude? Current estimates place it around mag. +10.5 at the start of December, brightening to mag. +9.9 by the year's end. If this trend is followed, the peak brightness on 10 May can be expected to be around mag. +8.7, placing it within binocular range.

At the time of writing, there is another comet visible in the UK's night sky: 2I/Borisov. It's the first comet discovered which has originated outside our Solar System.

2I/Borisov is faint and heading south in our skies. December presents your last chance to record it from the UK. It's an early morning object, passing through Crater for the first half of the month before diving south through Hydra. This period also coincides with the comet reaching its peak brightness of mag. +15.3 around the 19 December and closest approach to Earth of 1.98 AU on the 29th. At this brightness, recording 2I/Borisov will require either a giant scope, 18 inches (457mm) in aperture or more, or an imaging setup.

▸ **For details on imaging see page 76**



▲ **The path of comet 2I/Borisov, relative to star positions above the horizon, including 1 December (at 06:00 UT), 15 December (at 05:00 UT) and 31 December (at 04:00 UT)**

ALL PICTURES: PETE LAWRENCE

Planetary conjunctions

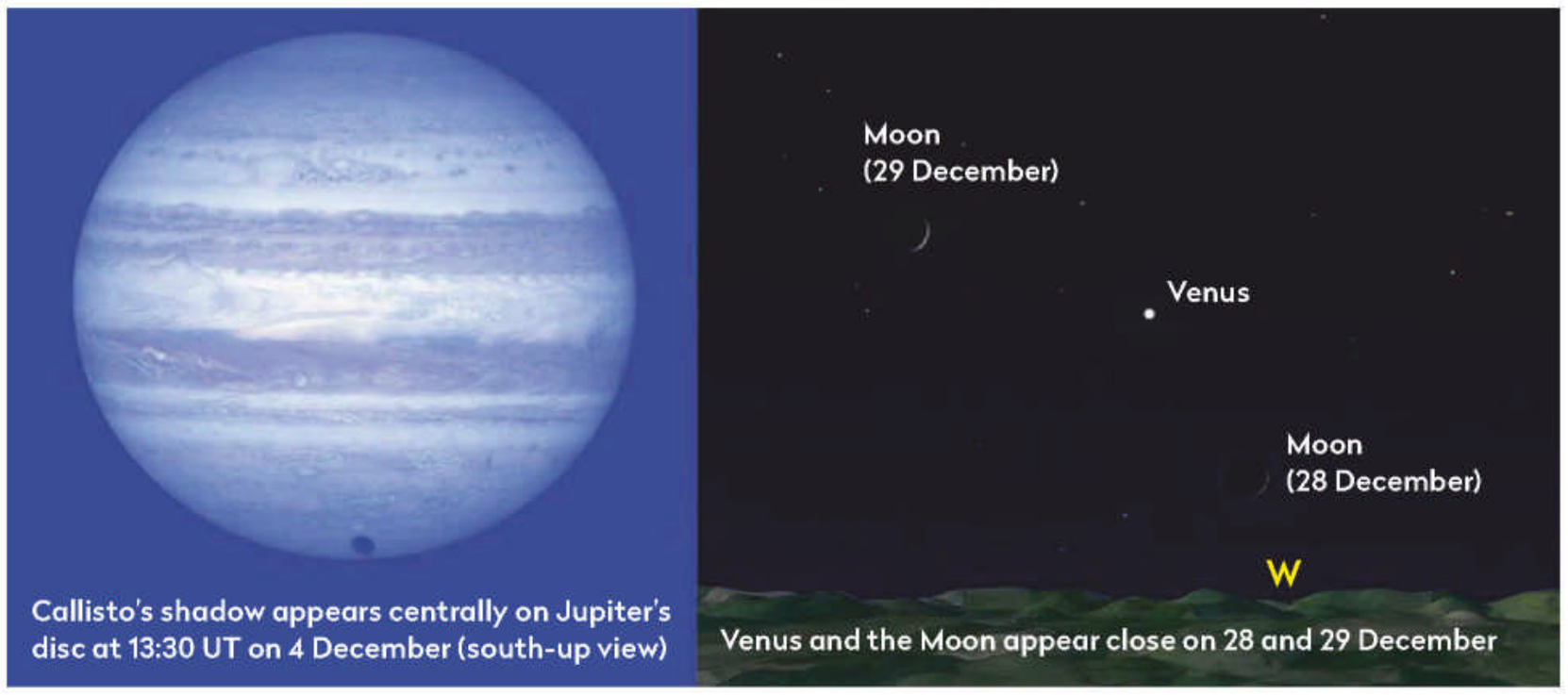
BEST TIME TO SEE: Evenings of 11, 28 and 29 December, and between 12:40–14:50 UT on 4 December for the Callisto transit

Venus, Jupiter and Saturn currently adorn the southwest sky after the Sun has set and can be seen changing relative positions throughout December. Jupiter and Saturn are bowing out from their current period of visibility, Jupiter reaching solar conjunction on 27 December, Saturn following suit a week later on 2 January 2020. Venus currently appears to be moving away from the Sun, its appearance improving over time. All three objects are located in the southern constellation of Sagittarius for most of the month, Venus crossing the border into Capricornus on 19 December.

As it slips east, Venus has a close encounter with Saturn on 11 December, both planets appearing separated by just 1.8° in the evening twilight after sunset on that date. It then continues moving eastward, managing to reach a separation from the Sun that allows it to be seen against dark skies later in the month. On the evenings of 28 and 29 December, Venus gets a visit from a slender waxing crescent Moon, a lovely target if you are set up for astrophotography.

At the start of the month, Venus appears at mag. –3.8, presenting an 11 arcsecond disc with 88% phase. By the end of December Venus's brightness will be mag. –3.9, its apparent diameter 13 arcseconds and phase at 82%.

Jupiter is compromised by the Sun's glare towards the end of the month but if you can catch it during daylight hours on 4 December, it may be possible to see the dark shadow of its outermost moon Callisto crossing the planet's disc from 12:40 UT until 14:50 UT. Jupiter is due south at 13:20 UT when it will have an altitude of 14° as seen from the centre of the UK. Callisto shadow transits aren't that common, only occurring when Jupiter is close to equinox, as will be the case next year.



▲ **Jovian moon Callisto makes a shadow transit and Venus lines up with a slender crescent Moon**

Geminids vs Ursids

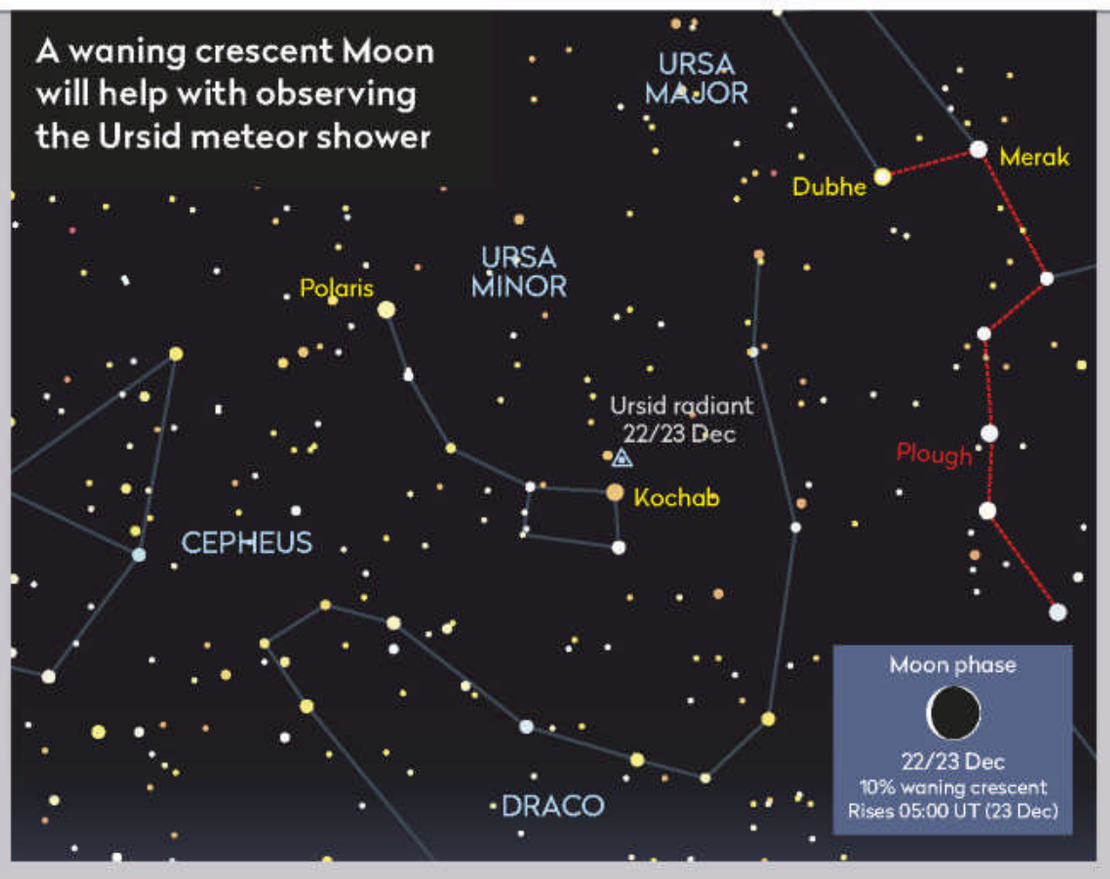
BEST TIME TO SEE: Geminids – the night of 13/14 December; Ursids – the night of 22/23 December

A regular highlight of December is the peak of the annual Geminid meteor shower. This is arguably the best shower of the year because it has a high ZHR (Zenithal Hourly Rate) of 120 meteors per hour, reliably showing a good number of meteors. In addition, December nights are long and dark, making them perfect for meteor watching. Contrast this with the popular summer shower, the Perseids, which has just four hours of true darkness as experienced from the centre of the UK.

Geminids peak night is 13/14 December when around 12 hours of true darkness (18:00–06:00 UT) can be experienced. Admittedly, these are at lower temperatures than you'd experience when observing the Perseids.

This year the Geminid peak is compromised by a bright just past full Moon. This rises at 17:10 UT on 14 December and hinders the number of visible meteors seen.

In contrast, the annual Ursid shower peaks on the night of 22/23 December when the 10%-lit waning crescent Moon rises at 05:00 UT on the 23rd. Although the ZHR for the Ursids is just 10 meteors per hour, the fact that it peaks under dark-sky conditions will make it a better prospect.



THE PLANETS

Our celestial neighbourhood in December

PICK OF THE MONTH

Mars

Best time to see: 31 December, 06:30 UT
Altitude: 9°
Location: Libra
Direction: Southeast
Recommended equipment: Naked-eye observing

Mars is a morning object and telescopically rather poor at the moment. The reason for this is that the planet's distance from Earth is currently high, Mars being on a far side of its orbit from Earth. As a consequence, when you peer at Mars though the eyepiece of a telescope it only presents a tiny 4 arcsecond disc throughout December. On the plus side, the planet does brighten slightly from mag. +1.7 at the start of December to +1.6 at the end, but admittedly this isn't a huge increase.

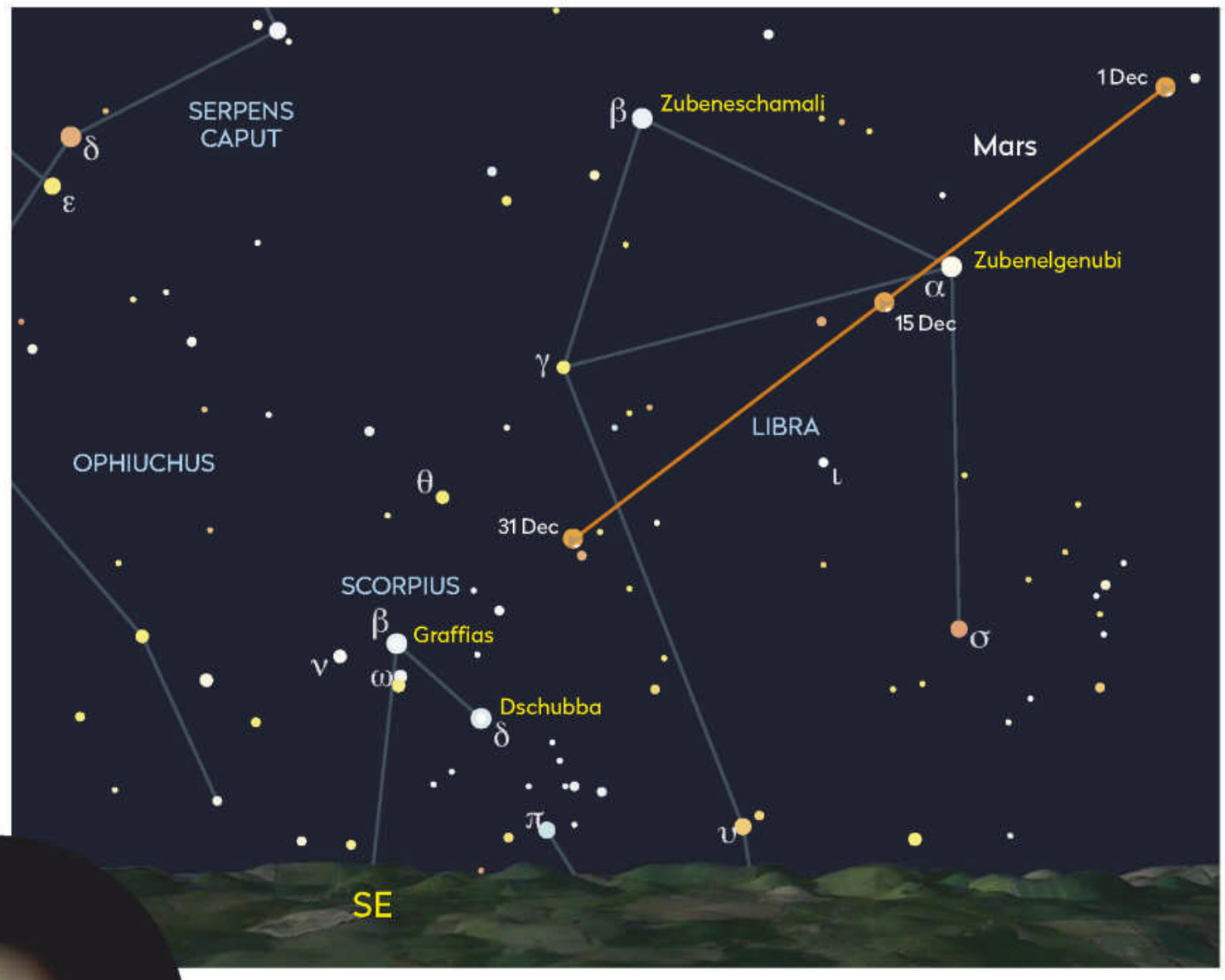
On 12 December Mars appears to sit 16 arcseconds from Zubenelgenubi (Alpha (α) Librae) and on the morning of 23 December, mag. +1.6 Mars is joined by a slender 9%-lit waning crescent Moon 3.2° to the left of the planet as seen from the UK. By the end of December, Mars rises 3.4 hours before the Sun.

PETE LAWRENCE X 3

▲ **Prospects for observing Mars will improve into 2020**

With such poor prospects, you might ask why we've picked Mars to be the planet of the month. The reason is that Mars is heading for a big improvement towards the latter part of 2020 and that will start to become noticeable over the next few weeks and months. Mars reaches opposition every 2.1 years and this is the best time to observe it through a scope. The last one occurred in 2018 and was poor for UK viewing, Mars being low down and difficult to see under steady skies.

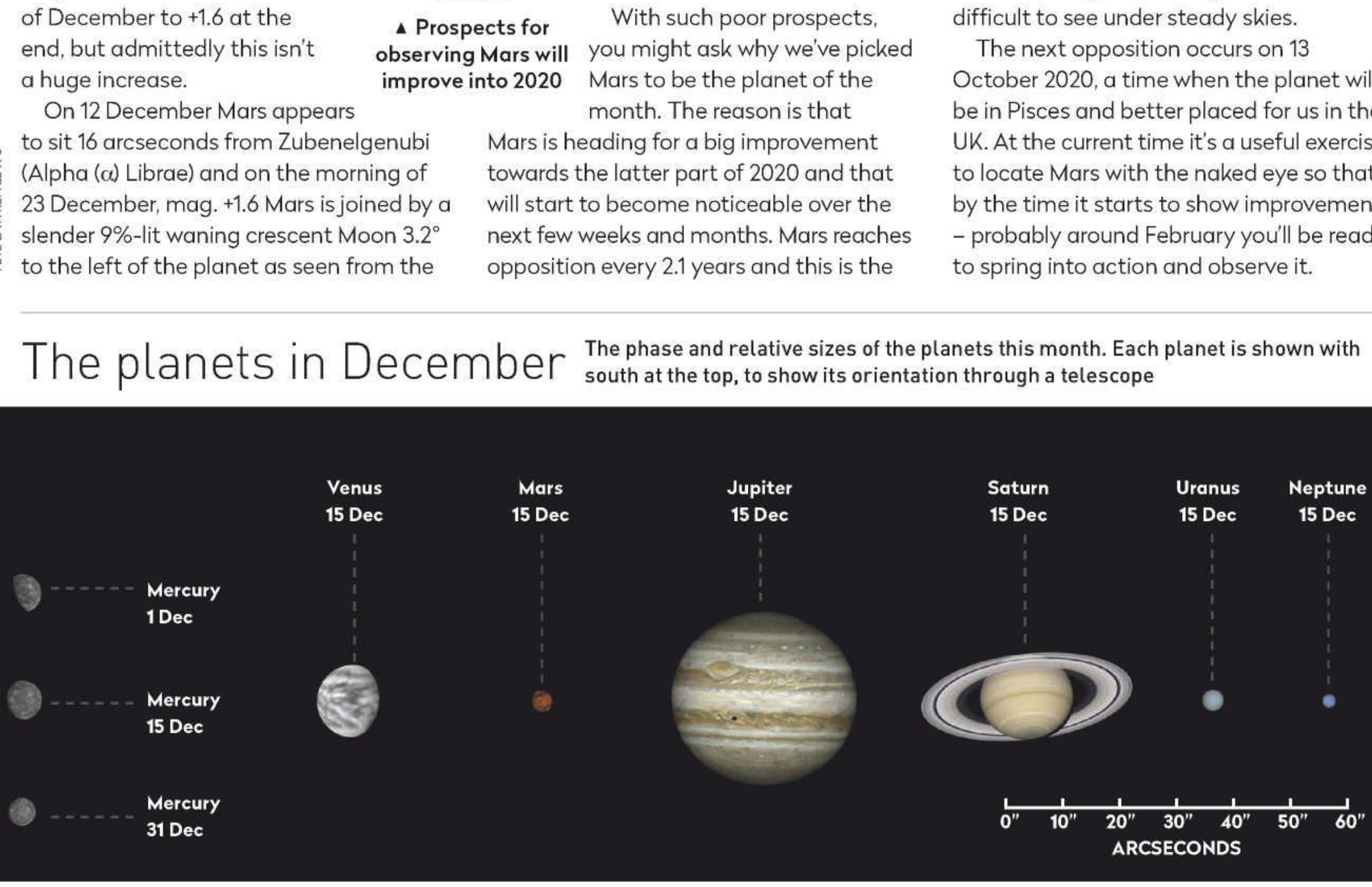
The next opposition occurs on 13 October 2020, a time when the planet will be in Pisces and better placed for us in the UK. At the current time it's a useful exercise to locate Mars with the naked eye so that by the time it starts to show improvement – probably around February you'll be ready to spring into action and observe it.



▲ **Keep an eye on the location of Mars throughout December 2019. The stars (above) are shown relative to the horizon at 06:30 UT on 31 December**

The planets in December

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



Mercury

Best time to see: 1 December, 60 minutes before sunrise
Altitude: 7° (low)
Location: Libra
Direction: Southeast

Mercury starts the month well; shining at mag. –0.5 it rises 120 minutes before the Sun. It's slowly moving back towards the Sun and by mid-month it stays at mag. –0.5, appearing 74 minutes before sunrise. It'll become less well-positioned but this is offset by an increase in brightness. The end of visibility will be around 25th when it'll be rising 1.6° from a slender crescent Moon.

Venus

Best time to see:
29 December, 17:00 UT
Altitude: 12°
Location: Capricornus
Direction: Southwest

Venus is an evening object, visible after sunset, low in the southwest. On 1 December its mag. –3.8 dot sets 90 minutes after the Sun. A scope shows an 89%-lit gibbous disc 11 arcseconds across. By the month's end, it will set three hours after the Sun and show a phase reduced to 82%-lit and a disc 13 arcseconds across.

Jupiter

Best time to see:
1 December, 16:45 UT
Altitude: 3° (very low)
Location: Sagittarius
Direction: Southwest

Jupiter is now too low for serious observation but remains an interesting target for naked-eye viewing at the month's start when, at mag. –1.7, it's joined by mag. –3.8 Venus and +0.9 Saturn. Jupiter is in solar conjunction on the 27th.

Saturn

Best time to see: 1 December, 17:15 UT
Altitude: 9° (low)
Location: Sagittarius
Direction: Southwest

Saturn appears as a mag. +0.9, slightly yellowish dot, low above the southwest horizon as darkness falls on 1 December. Towards the month's end it will be all but lost in the evening twilight. Before it disappears, look low towards the southwest horizon on the evening of 11 December where you should see mag. +0.9 Saturn 1.8° north of mag. –3.9 Venus. As a final Saturnian challenge for 2019, see if you can spot the planet after sunset on the 27th when there's a slender crescent Moon 2.7° below the mag. +0.9 planet.

Uranus

Best time to see:
1 December, 19:30 UT
Altitude: 49°
Location: Aries
Direction: South

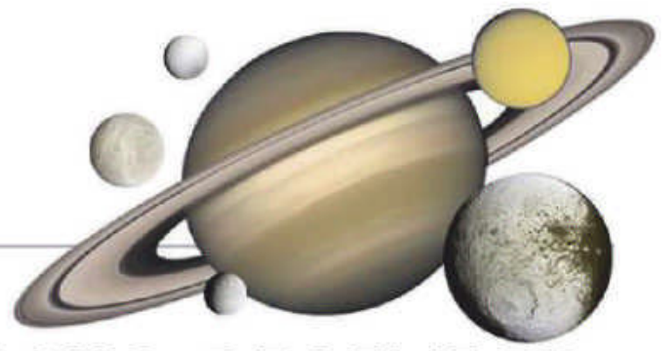
Uranus is well placed, reaching its highest point above the horizon when due south in darkness all month long. At mag. +5.7 it may be glimpsed with the naked eye from a dark sky site. Uranus is residing in the southwest corner of Aries.

Neptune

Best time to see: 1 December, 18:30 UT
Altitude: 30.5°
Location: Aquarius
Direction: South

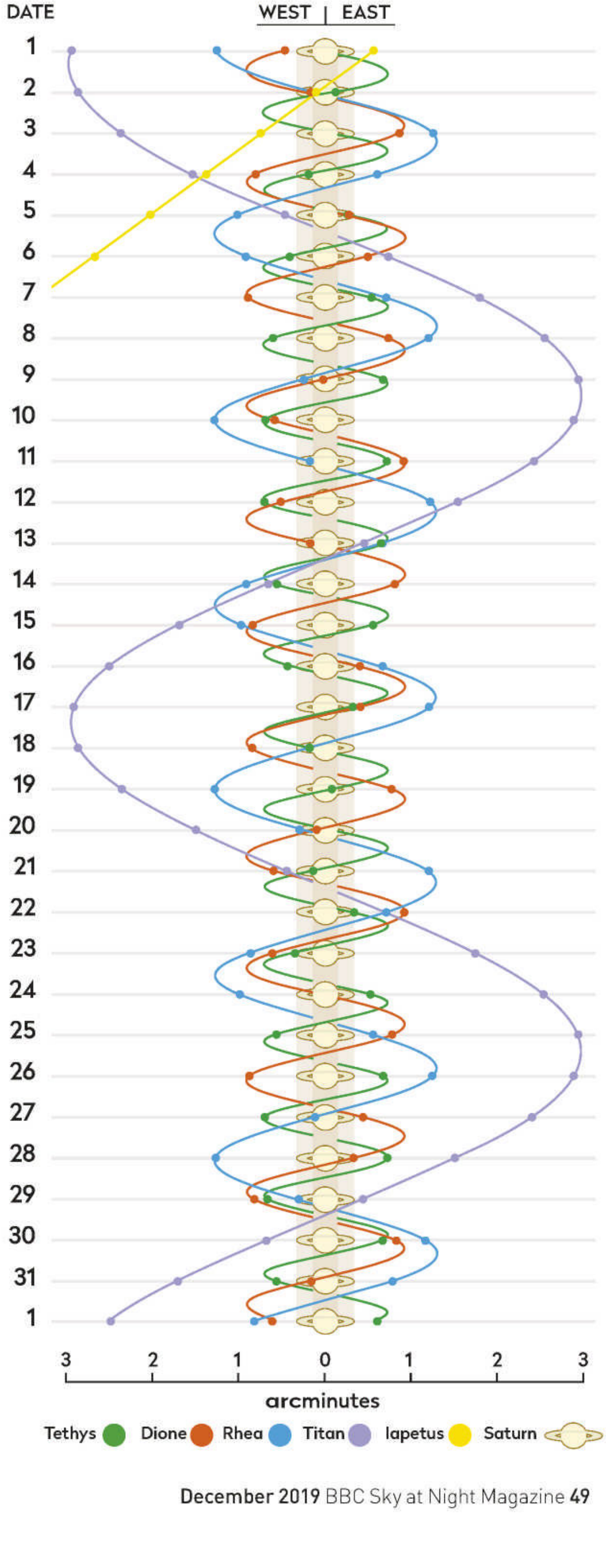
Neptune is well placed at the start of December, able to reach its highest point in the sky, around 30° up, in darkness. At mag. +7.9 you'll need at least binoculars to spot it just southwest of mag. +4.2 Phi (φ) Aquarii. By the end of December, Neptune begins to lose altitude above the south-southwest horizon as darkness falls.

More **ONLINE**
Print out observing forms for recording planetary events



SATURN'S MOONS: DECEMBER

Using a small scope you can spot Saturn's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – DECEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

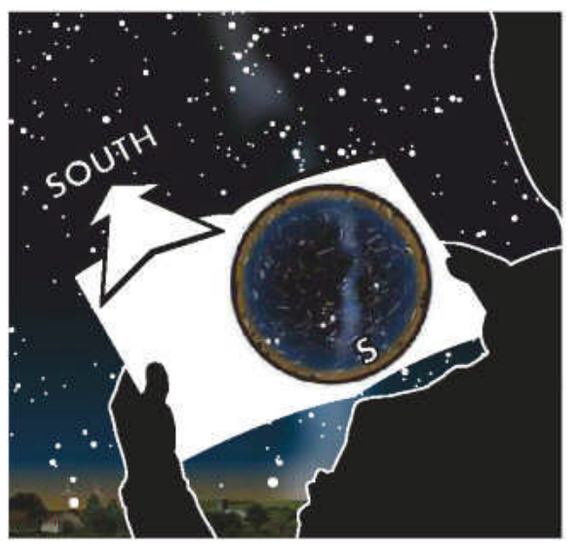
When to use this chart

1 December at 00:00 UT
15 December at 23:00 UT
31 December at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.



Sunrise/sunset in December*

Date	Sunrise	Sunset
1 Dec 2019	08:02 UT	15:55 UT
11 Dec 2019	08:15 UT	15:51 UT
21 Dec 2019	08:24 UT	15:52 UT
31 Dec 2019	08:26 UT	16:00 UT

Moonrise in December*

Moonrise times

1 Dec 2019, 12:19 UT	17 Dec 2019, 22:05 UT
5 Dec 2019, 13:44 UT	21 Dec 2019, 02:13 UT
9 Dec 2019, 14:48 UT	25 Dec 2019, 07:33 UT
13 Dec 2019, 17:05 UT	29 Dec 2019, 10:48 UT

*Times correct for the centre of the UK

Lunar phases in December

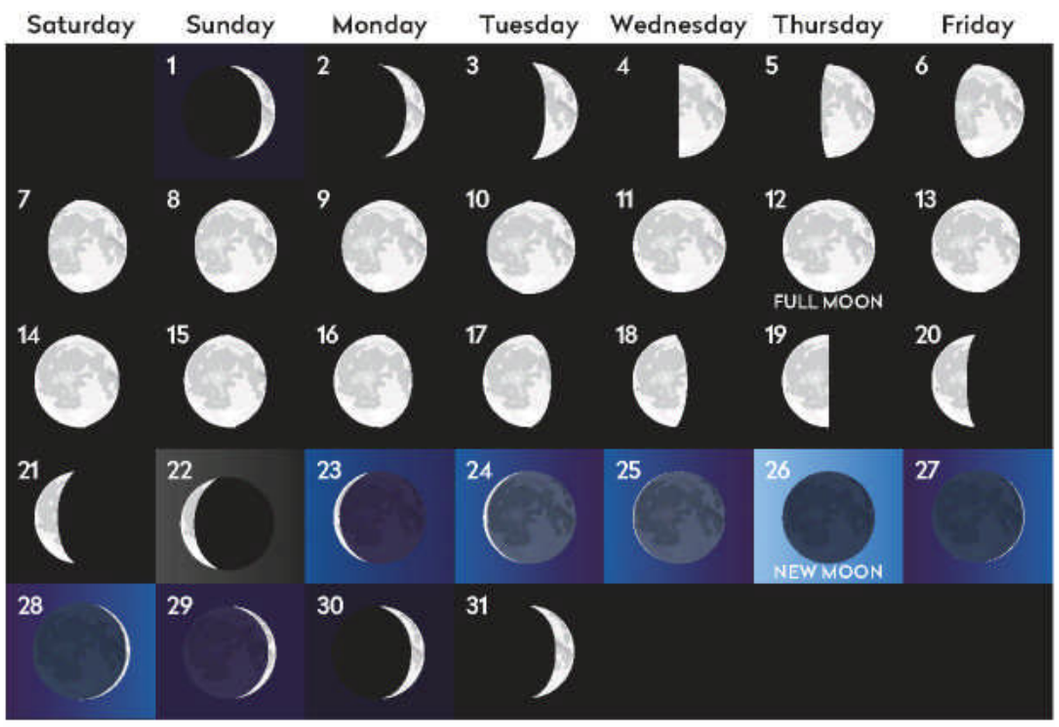
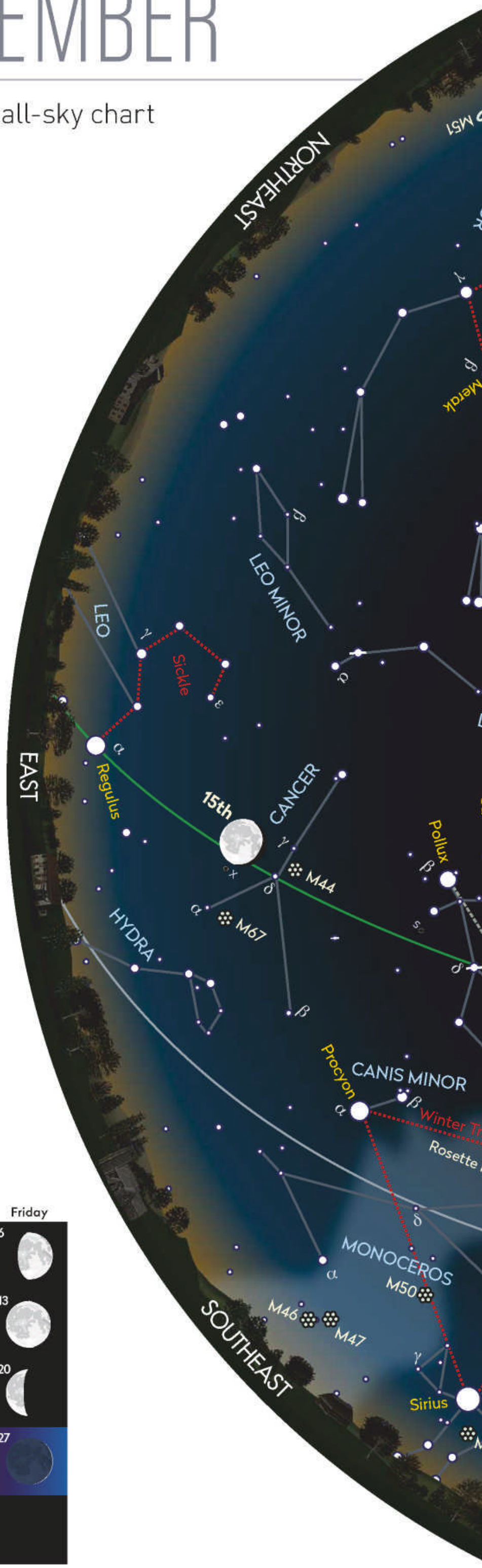
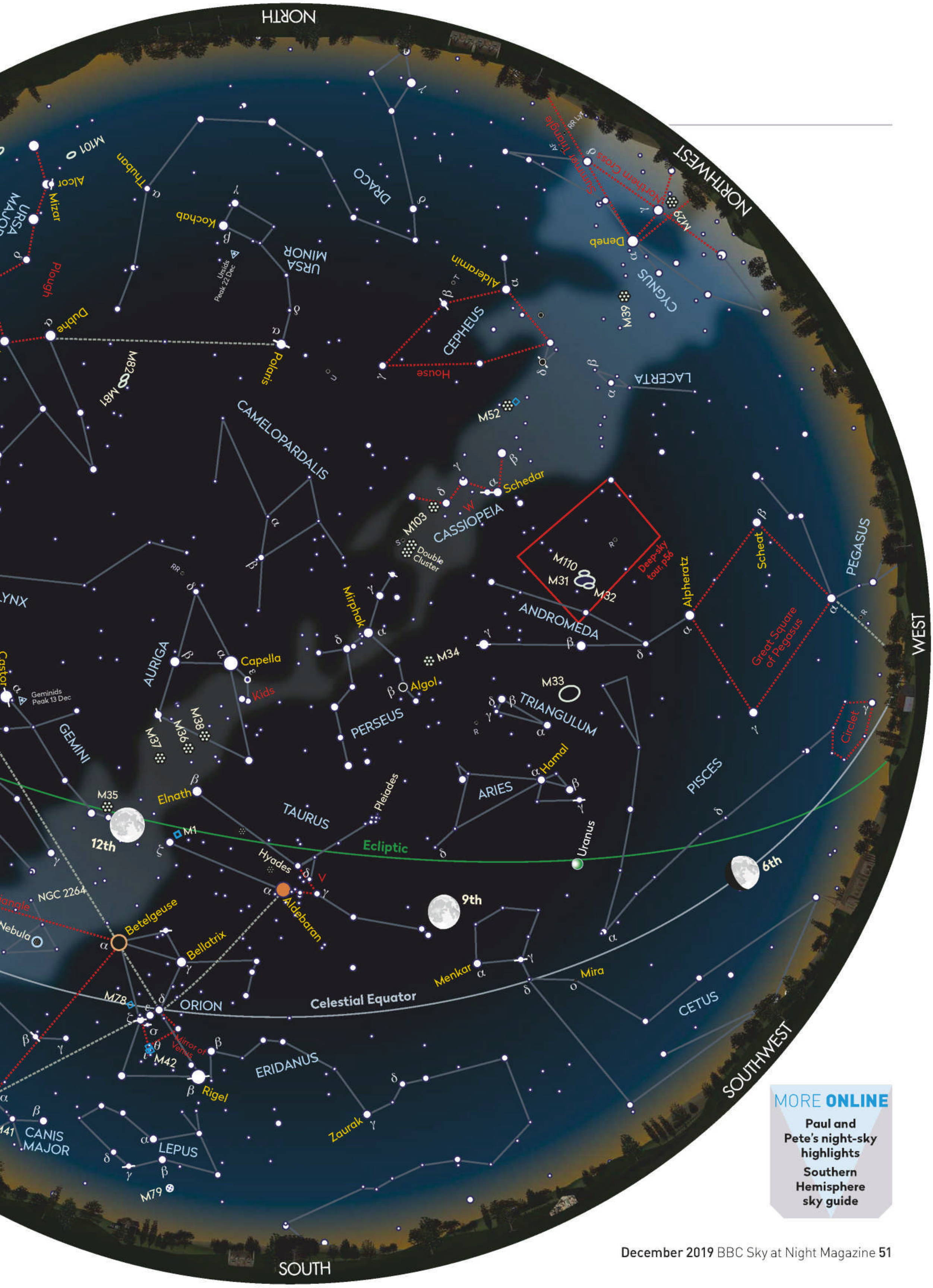


CHART: PETE LAWRENCE





MORE **ONLINE**

Paul and Pete's night-sky highlights

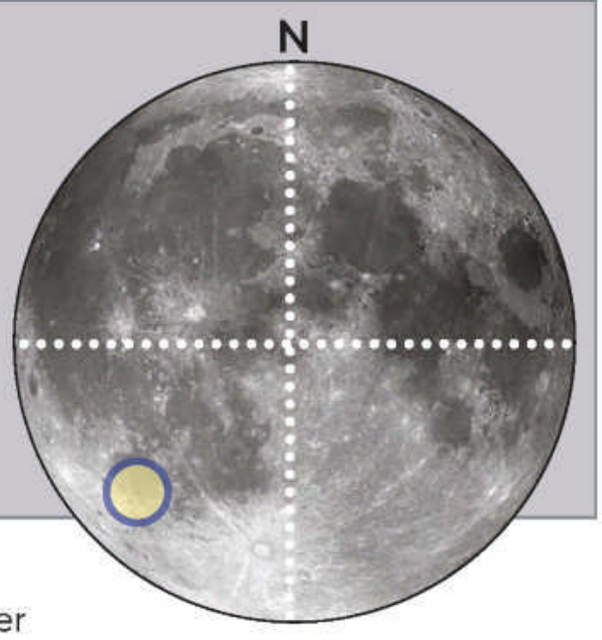
Southern Hemisphere sky guide

MOONWATCH

December's top lunar feature to observe

Doppelmayer

Type: Crater
Size: 65km
Longitude/latitude: 41.6° W, 28.5° S
Age: Around 3.9 billion years
Best time to see: Three days after first quarter (7–8 December) and two days after last quarter (21–22 December)
Minimum equipment: 50mm refractor



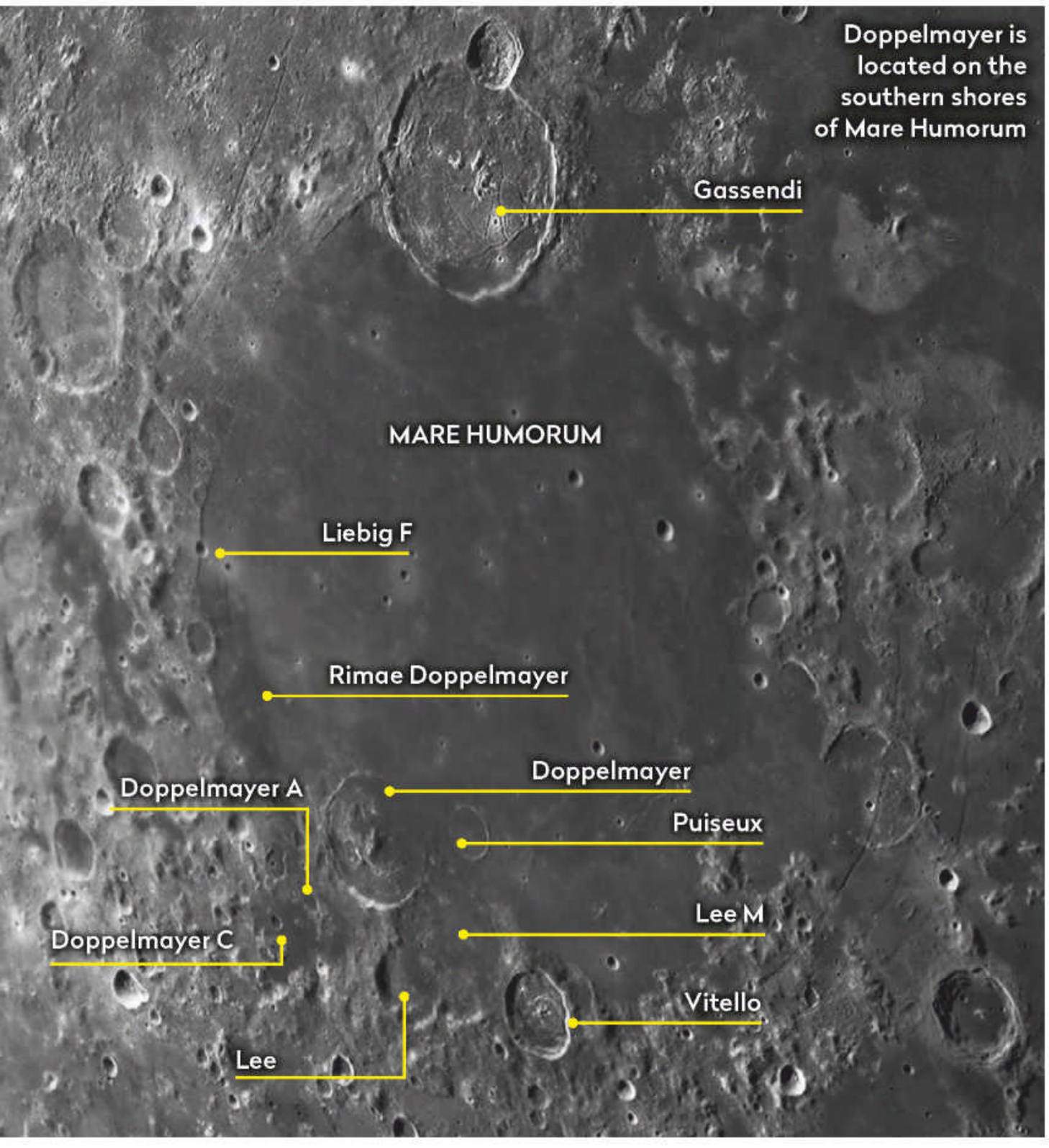
PETE LAWRENCE X 5

Doppelmayer is a moderately sized crater formation located on the southern shores of 380km diameter **Mare Humorum**. Here it joins an interesting cluster of craters including 41km Lee, 77km Lee M, 41km Vitello and 25km Puiseux. Aesthetically, this group visually balances the appearance of Mare Humorum, the northern shore of which is defined by the large and complex form of 110km **Gassendi**.

Doppelmayer has an interesting appearance. It is flooded with lava but, unlike neighbouring Lee M, just manages to retain a full rim. Or does it? The rim is well defined from the northwest travelling counter-clockwise around to the southeast. The section of northern rim clockwise through to the east, appears to be there under certain lighting conditions, but it's hard to say whether this is actually the case. Visually, there's a strong urge to 'complete the circle' and under oblique lighting there appears to be a ridge or sorts running across the lava where the northern rim should be. However, under close scrutiny this appears to be more akin to a small wrinkle ridge on the surface of Mare Humorum.

Lava has invaded Doppelmayer's northeast third but the remaining two-thirds have stubbornly held fast. This region retains a more typically crater-like appearance with a central peak and surrounding rough terrain hills. The central peak is well-defined and contains a tiny crater pit at its peak, something of a challenge if you're into lunar imaging. The peak's surrounding hills have a distinctly curved visual appearance to them, looking strikingly concentric to the main crater's rim.

Lava has invaded Doppelmayer's northeast third, but the remaining two-thirds have held fast



Craters **Lee** and **Lee M** to the southeast are similar in that they have their northern rim arcs missing due to being submerged under Humorum's lava. It's also interesting to compare the rather beautiful internal arcs of Doppelmayer with the large flat plain of Lee M.

Puiseux to the northeast of Doppelmayer is a delicate crater ring – the remains of a crater almost totally submerged beneath the surface of Mare Humorum. Here though we have a complete ring, slightly asymmetrical in that the eastern arc rises marginally higher than that seen to the west. Of the group of craters nestled against the southern edge of Humorum, **Vitello** has the best definition. Its sharp rim appears to have a surprisingly regular appearance all the way around. Vitello's central mountain complex is well presented with a rough, hilly and cracked terrain surrounding it.

Most of Doppelmayer's labelled satellites appear southwest of the main crater. A small lake-like area of dark lava infills the highland region here. **Doppelmayer A** is a 10km filled crater located 60km southwest from Doppelmayer's central peak. **Doppelmayer C** (7km) lies 28km further to the southwest, within the lake-like lava region. If you head west from Doppelmayer and follow the inside edge of Mare Humorum, here you'll find a long and narrow feature known as **Rimae Doppelmayer**. This 130km-long feature can be hard to see unless you are using a 300mm or larger instrument because it measures a mere 1.5km in width. It continues across the mare's lava ending close to the 9km crater **Liebig F**.

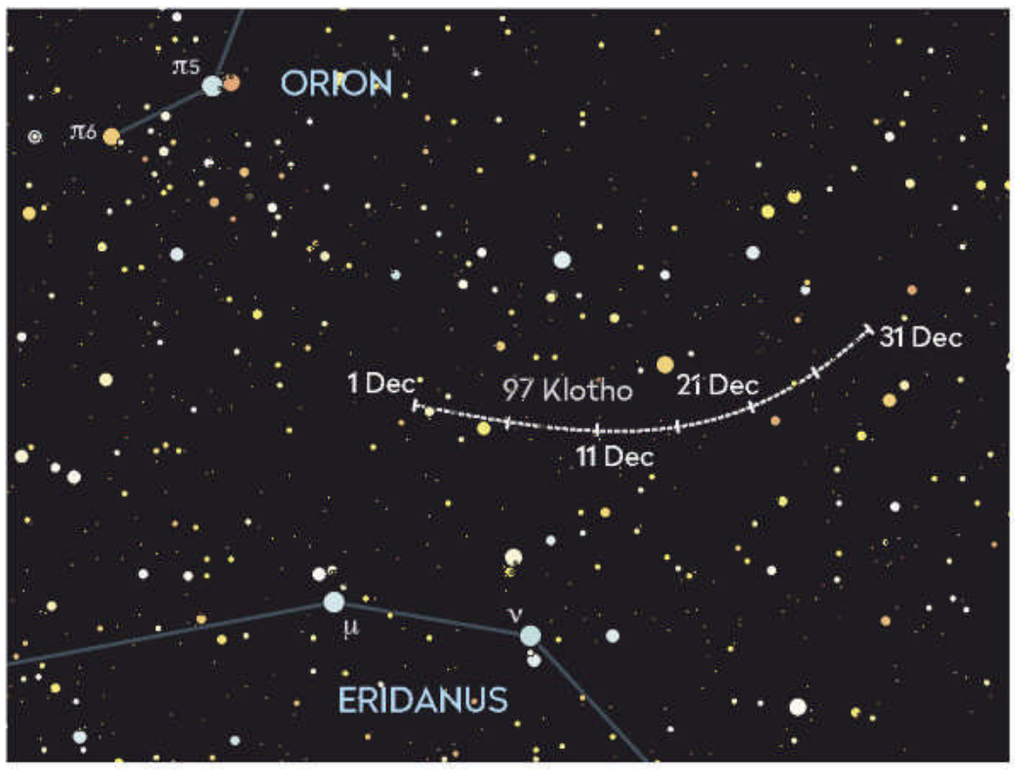
COMETS AND ASTEROIDS

Discover minor planet 97 Klotho as it tracks through the northern part of Eridanus

Minor planet 97 Klotho reaches opposition on 1 December. It spends most of the month in the northern part of Eridanus and appears at a decent height above the southern horizon – similar to the altitude of Orion's Belt – when positioned due south. At the month's start it shines by reflected light at mag. +9.9 dropping slightly to mag. +10.4 by December's end. This makes it a good target for a small scope or binoculars. The best way to 'see' Klotho is to look at the part of sky indicated in our chart and draw or photograph this region, recording stars down to 11th magnitude. Repeat the exercise over the course of several nights – they don't need to be consecutive if the weather interferes – and the 'star' that appears to move between results is likely to be the minor planet.

At the start of December Klotho is located 2.5° north and a fraction to the west of the fourth magnitude star Mu (μ) Eridani. Mu and similar magnitude Nu (ν) Eridani form a convenient navigational platform from which to look for the asteroid. Throughout the month Klotho follows an arcing path to the west and northwest covering about 6°.

Klotho is a large main-belt asteroid, slightly larger than 80km across. It's classed as an M-type asteroid, a type with a composition that is only partially known. They are thought to be pieces of the metallic core of impact-fragmented larger asteroids. Some of them are made of nickle-iron while others have stone mixed in as well. In the case of Klotho, its reflectance has been observed to be too low for a purely nickel-iron composition.



▲ **Use this chart of background stars to help locate 97 Klotho**

Klotho was discovered in 1868 by Ernst Wilhelm Tempel. Analysis of the object's asymmetric light curve over an extended period in 1990 determined a rotation period close to 11 hours in length.

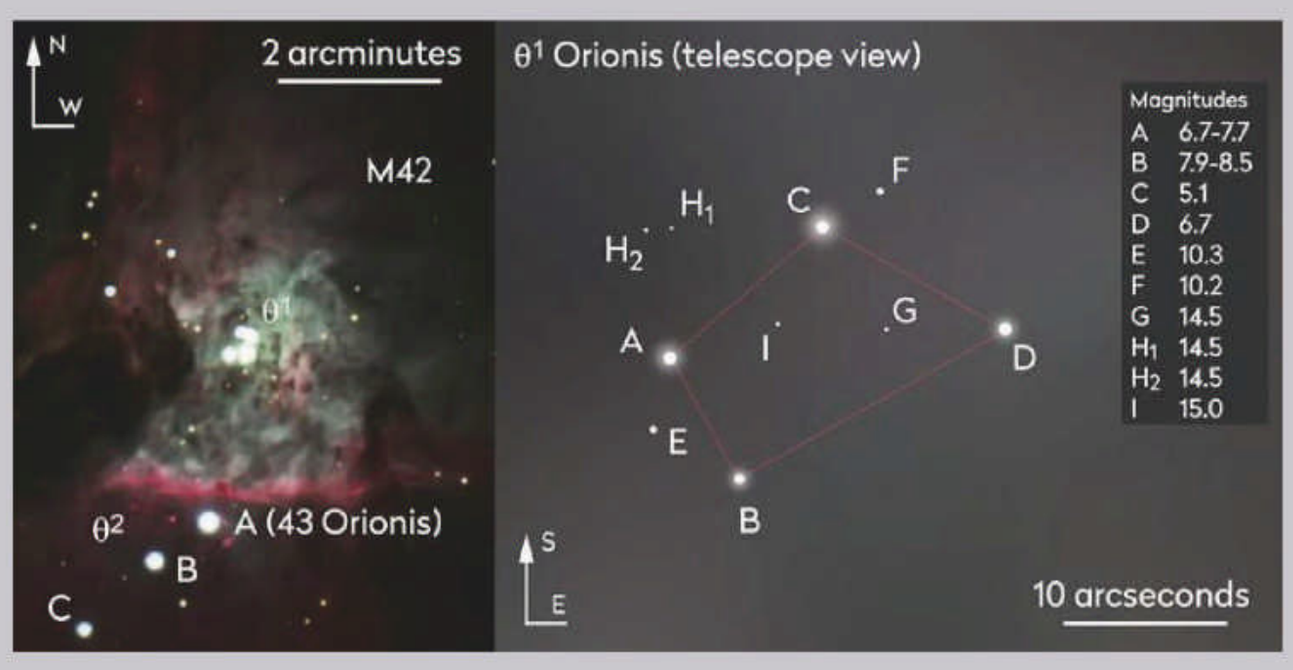
STAR OF THE MONTH

Theta-1 Orionis, at the heart of Orion

Theta (θ) Orionis is a star at the centre of the Orion Nebula, M42. Except it is not a single star at all. Look into the nebula's heart and you'll see a group of stars that contain four brighter members, collectively known as the Trapezium. This is also known as Theta-1 (θ^1) Orionis. Actually, the Trapezium is just the tip of the iceberg, the four components being the brightest members of the Trapezium cluster, an open cluster of stars born out of the nebula material. Some of the other cluster members are visible using amateur scopes and it's a challenge to see them. The brighter members of the cluster are labelled Theta-1 Orionis A to H.

As seems fitting for stars located in such a venerable part of the sky, each of the components, A to H, has characteristics which makes it special. Theta-1 Orionis A is a triple system while B is a quintet. C is a binary while D is variable. E is a spectroscopic binary, F a variable star, G is a young star system known as a proplyd, H actually being two proplyds labelled H1 and H2.

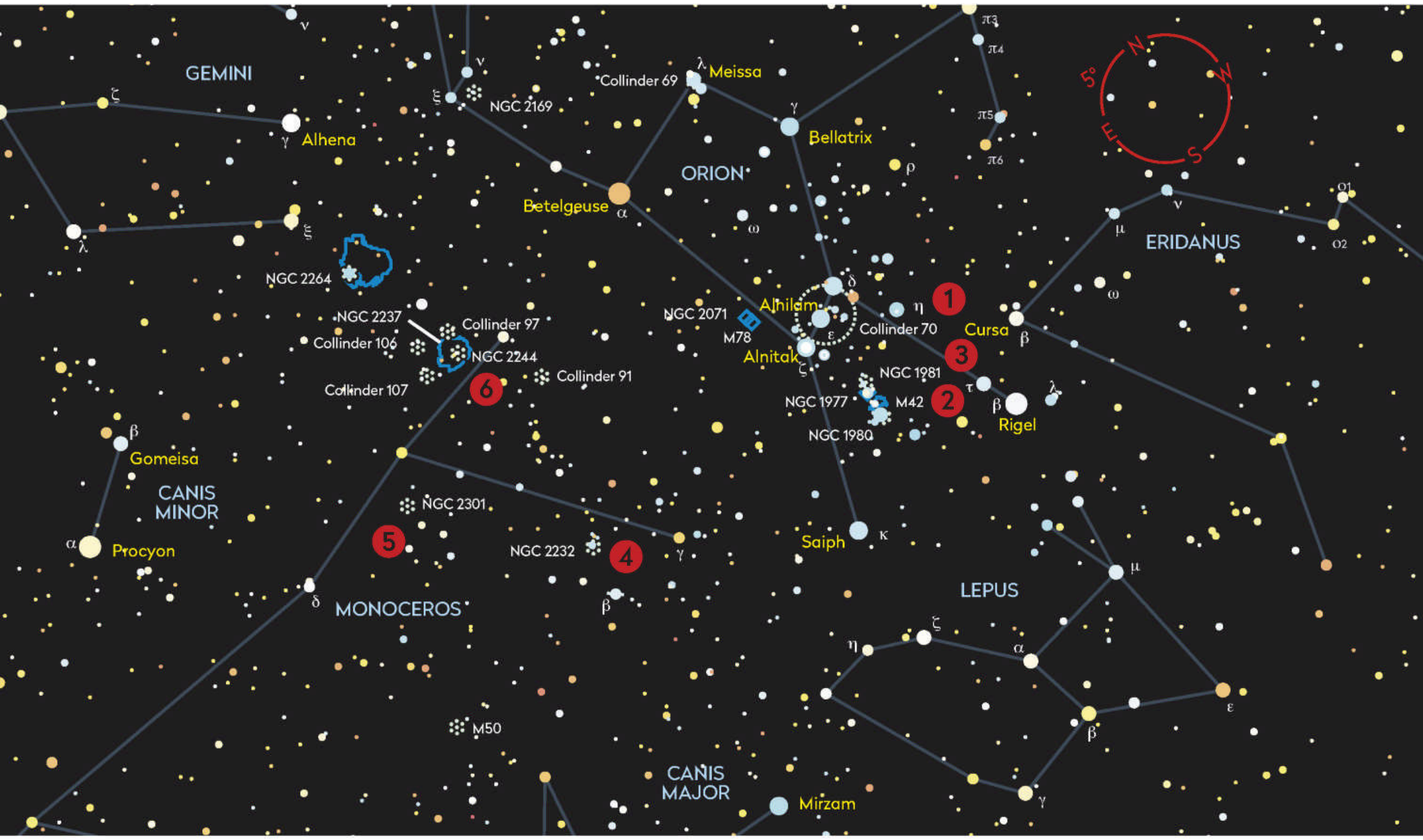
Theta-1 Orionis was discovered by Galileo in 1617. His recording of the cluster described three stars but he failed to record the surrounding bright nebula. He saw the glow but thought it was an unresolved star cloud, fuzzy due to his scope. Theta-1 Orionis is only part of the picture. Theta-2 is located 2.3 arcminutes southeast of the Trapezium and comprises three stars in a line, each spaced about an arcminute from the other. Theta-2 A, also known as 43 Orionis, is a spectroscopic triple star system. Theta-2 B is variable and Theta-2 C is binary. Next time you look at the Orion Nebula, consider the beauty of the stars that lie at its heart.



▲ **A closer look at Theta-1 Orionis reveals a rich array of star cluster members**

BINOCULAR TOUR With Steve Tonkin

Our wide-field gems include Collinder 70 and the star clusters around Orion's belt



1. Collinder 70

10x 50 We'll start with Collinder 70, a cluster that you may have seen without realising: it is the huge, oval-shaped group of mostly blue-white stars surrounding Orion's Belt. On a clear night, you should be able to see about 70 stars, many in pairs and chains. Make a point of finding the S-shaped chain of brighter stars that weaves its way between Alnilam (Epsilon (ε) Orionis) and Mintaka (Delta (δ) Orionis). ☐ **SEEN IT**

2. M42

10x 50 The Orion Nebula, M42, is visible to the naked eye as the central 'star' of Orion's Sword. Although it's a lovely object in binoculars of any size, it is susceptible to light pollution: a dark transparent sky will reveal much more intricate detail. It benefits from patience and it seems that the longer you look, the more you see, until you begin to get an almost three-dimensional sense of depth. ☐ **SEEN IT**

3. NGC 1981

15x 70 By now you will have realised that the other two 'stars' of Orion's Sword are actually clusters. Slightly above the upper 'star' is a sparse accumulation of stars that looks like a letter F which has fallen over; this is NGC 1981. It is unremarkable as an object, but interesting in that it indicates the fate of the Orion Nebula. Millions of years ago, this cluster would have had nebulosity around it, much like M42 has today. ☐ **SEEN IT**

4. NGC 2232

10x 50 Identify the blue-white star, Beta (β) Monocerotis, and look a little more than 2° north of it where, just visible to the naked eye, you'll see a small fuzzy patch. Binoculars will reveal 10 or more stars, spread out across an area of sky the same apparent size as the Moon. These form two distinct wedge-shaped groups, with the two brightest stars (10 Mon and 9 Mon), each at the tip of a wedge. ☐ **SEEN IT**

5. NGC 2301

15x 70 Our next cluster can be tricky to find, but it's worth it. You'll find it 5° west of Delta (δ) Monocerotis. Look for a little 'T-junction' of 8th and 9th magnitude stars; our cluster is at the confluence, covering a little more than 10 arcminutes and appearing as a few brighter stars against the mottled glow of the 40 or so distant suns that comprise the cluster. ☐ **SEEN IT**

6. NGC 2244

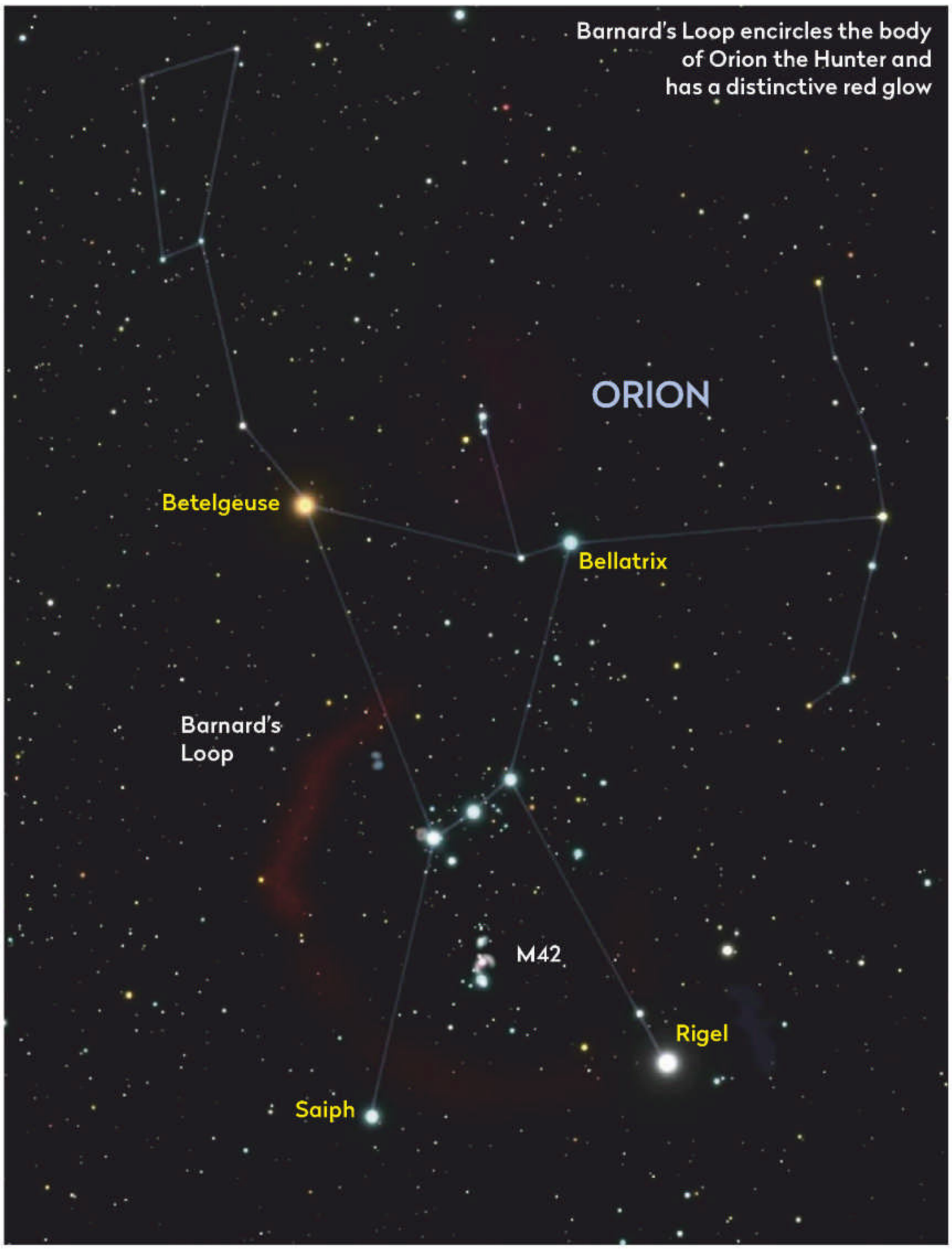
10x 50 Just 2° east of Epsilon (ε) Monocerotis is a rectangular group of stars about 25 arcminutes long, that looks more like a denser accumulation in the Milky Way than a cluster. You'll probably see about a dozen stars together but, unless you have exceptional skies, don't expect to detect the surrounding glow of the Rosette Nebula, from which these stars formed. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you observe and image Barnard's Loop, the red arc in the constellation of Orion?



Barnard's Loop encircles the body of Orion the Hunter and has a distinctive red glow

▲ Binoculars made from two cardboard tubes will help remove general sky glow

This month's challenge is to observe or record Barnard's Loop, a huge, dim glowing ring that encircles the body of Orion the Hunter. The loop is incomplete, the western half being essentially invisible even in really deep exposure photographs. What remains looks more like a giant letter 'C' with its top just south of the mid-point between Betelgeuse (Alpha (α) Orionis) and Bellatrix (Gamma (γ) Orionis), stretching south to a point just east of Rigel (Beta (β) Orionis).

The loop, also known as Sharpless 2-276, glows mostly due to excited hydrogen and as a consequence has a strong red colour in long exposure photographs. Its vertical dimension is around 13° and it's the northern half of the 'C' shape, or if you prefer, the northeast quadrant, which glows brightest and may be seen with the naked eye.

It has a very low surface brightness and in order to stand any chance of seeing it at all, you'll need to have access to a dark-sky site. Additionally, it's imperative to only try when there are no other light sources around. This includes artificial lights and natural light from objects such as the Moon or even Venus.

The use of narrowband filters such as those used for hydrogen-alpha and hydrogen-beta deep-sky work are recommended if you have them. Ideally, if you have access to two filters of the same type, using one for each eye will give you the best chance. It may seem like an odd suggestion, but creating binoculars with no optics out of two cardboard tubes may also help as this removes any distraction or interference from general sky glow.

Make sure you give yourself at least 20 minutes in complete darkness before trying. This will allow your eyes to properly dark adapt and be at optimum sensitivity. The use of averted vision, a technique where you look off to the side of a faint object to place its delicate light onto a more sensitive part of your retina, is also highly recommended.

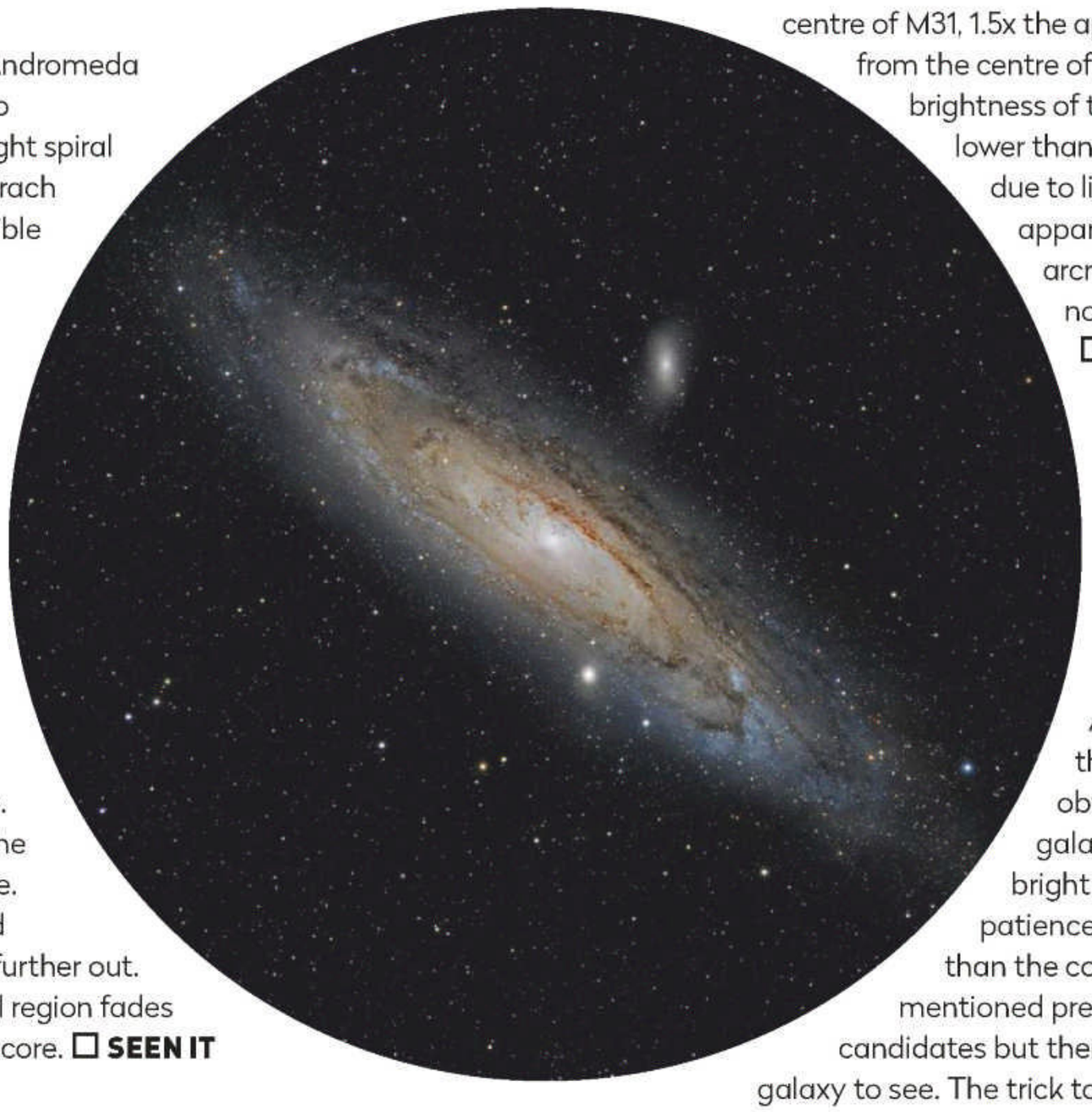
Using a garden recliner will help too because it's harder to see faint objects when you're uncomfortable. Position the recliner so you lie back, looking directly at Orion.

The less arduous method of 'seeing' Barnard's Loop is to photograph it. If you plan to use a regular DSLR, you may struggle due to the over-zealous infrared filter used in many models. This tends to reduce hydrogen-alpha sensitivity quite substantially. The ideal choice is a monochrome astronomical camera fitted with a hydrogen-alpha imaging filter.

If you do succeed, please let us know. And don't forget to send any photos you get of this iconic feature to our Gallery at **contactus@skyatnightmagazine.com**

DEEP-SKY TOUR

We take in the best celestial sights around the Andromeda Galaxy, M31



▲ **Begin your journey into the Andromeda Galaxy by finding the dark dust lane on its northwest edge**

1 M31

Messier 31, the Andromeda Galaxy, needs no introduction. It's a large bright spiral galaxy 7.7° northwest of Mirach (Beta (β) Andromedae). Visible to the naked eye, a small scope reveals that the famous elongated glow is just the core of the galaxy, an ellipse approximately 30x10 arcminutes in size. The fainter spiral arms sit outside the core. A low power shows the galaxy off best. Start your journey into M31 by looking for the dark dust lane which runs along the northwest edge of the core. Look for the faint glow of the spiral arms beyond this lane. This glow continues toward another dark lane located further out. Notice also how the central region fades inwards towards a star-like core. ☐ **SEEN IT**

2 M32

A measure can be made of how good your skies and eyes are by looking at how far M31's core extends from the galaxy's centre. One measure for this is satellite galaxy M32 which sits 24 arcminutes south of M31's star-like core. This mag. +8.1 elliptical appears like a large fuzzy star at low powers. M31's elliptical core should extend, along its main axis beyond M32. If it reaches the 7th magnitude star HIP 3293, 13 arcminutes southwest of M32, you're doing well. M32 itself appears non-circular, an oval glow measuring 3x2 arcminutes. Like M31, the core of M32 appears almost stellar in nature, but larger apertures will reveal it as an extended region about 10-15 arcseconds across. M32 is an elliptical dwarf galaxy with a mass equal to around 3 billion Suns. ☐ **SEEN IT**

3 M110

Like M32, M110 is another gravitationally bound satellite galaxy of M32 and another elliptical galaxy. It appears fainter and more elongated than M32, M32 being classed as type E2 while M110 is type E6p. M110 sits 35 arcminutes northwest of the centre of M31, 1.5x the apparent distance of M32 from the centre of M31's core. The surface brightness of this mag. +8.5 galaxy is lower than M32's and it can be lost due to light pollution. It has an apparent size about 10x3 arcminutes, appearing like a north-south aligned streak. ☐ **SEEN IT**

4 NGC 206

We return to the main galaxy for our next object, NGC 206, a bright star cloud. When observing the Andromeda Galaxy through a scope, it is obvious that the main galaxy is dominated by its bright core. And it takes patience to see anything other than the core. The dark dust lanes mentioned previously are obvious candidates but there are other parts of the galaxy to see. The trick to finding NGC 206 is to use the obvious visible components – the centre of M31 and M32. The star cloud lies at one vertex of a squat isosceles triangle formed using M32 and M31's star-like core, M32 being the apex of the triangle. NGC 206 is truly a part of M31. ☐ **SEEN IT**

5 NGC 185

M32 and M110 are often cited as M31's satellite galaxies, but they're not the only ones. NGC 185 is another example. To see it you'll need to move into Cassiopeia and head 7° north of M31 to arrive at mag. +4.5 Omicron (ο) Cassiopeiae. Mag. +9.2 NGC 185 sits 1° to Omicron's west. This lesser-known satellite of M31 is a moderately bright dwarf spheroidal galaxy. A 150mm scope will reveal it as about 4 arcminutes across, a bit elongated in an east-west direction. It appears 25 per cent larger in a 250mm scope, with a more circular appearance. ☐ **SEEN IT**

6 NGC 147

NGC 147, is a tricky object, even with large instruments. Head west from NGC 185 for 1°, nudging a little north. This is another dwarf spheroidal galaxy and another M31 satellite. A 300mm instrument will show it as a faint smudge, 3x2 arcminutes in size, appearing to brighten as you head into the centre towards a stellar nucleus. Like M31, it's around 2.5 million lightyears from us. All of the galaxies we've visited this month are part of the Local Group of Galaxies, of which the Milky Way is a member. ☐ **SEEN**

ROLF GEISSINGER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.

CASSIOPEIA

01h00m

00h30m

00h00m

23h30m

+45°

NGC 185

NGC 147

o

π

5

6

N

2°

1°

E

W

S

1

Normal limit
of spiral arms recorded
on long exposure
photographs

Inner dust lane
(northwest)

Core

3

M110

Outer dust lane
(northwest)

ν

Dust lane
(southeast)

2

M32

NGC 206

HIP 3293

4

M31

1°

30'

1

M31

3

M110

ν

2

M32

+40°

01h00m

μ

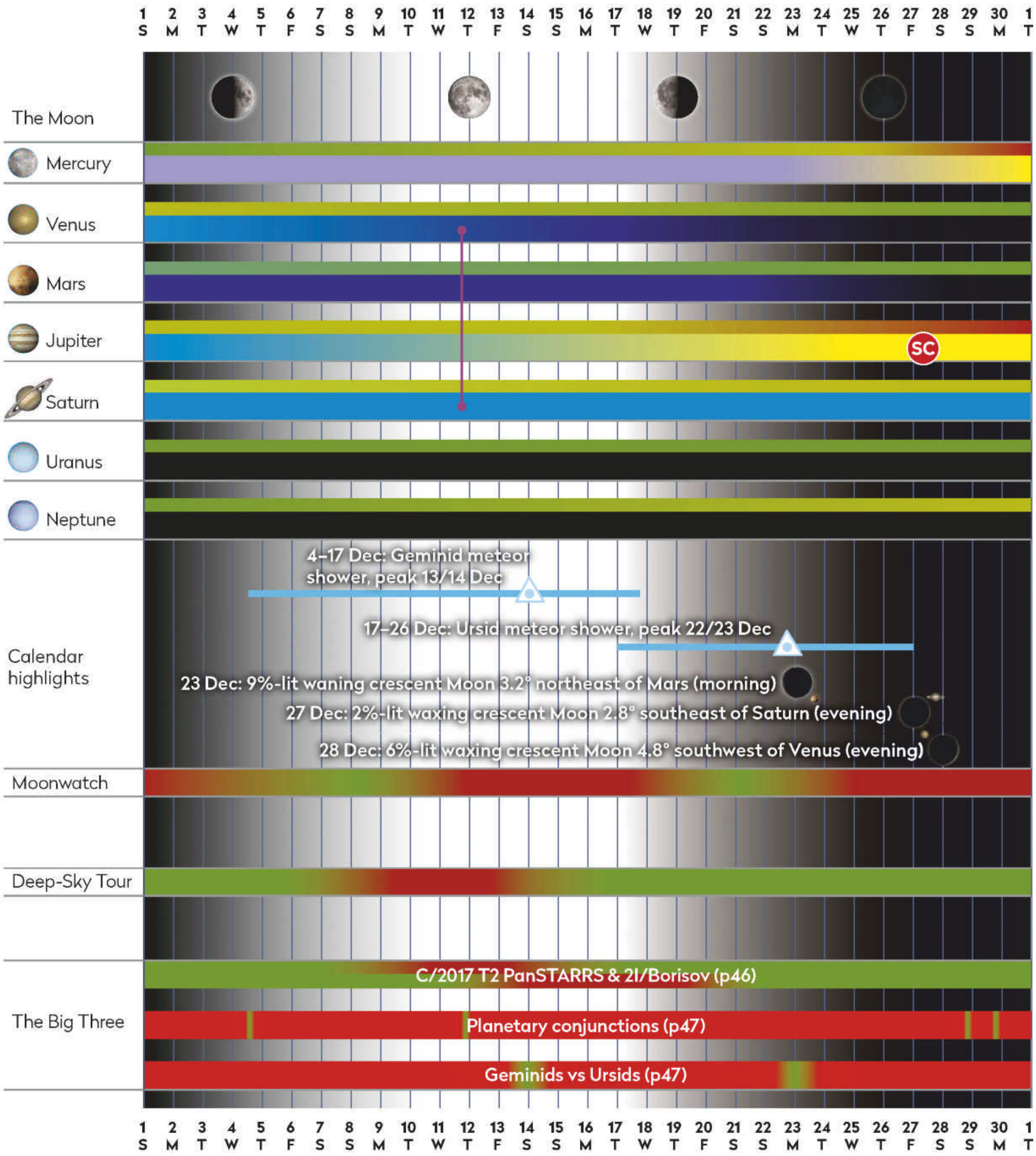
ANDROMEDA

01h30m

00h00m

AT A GLANCE

How the Sky Guide events will appear in December



KEY

CHART BY PETE LAWRENCE

Phaethon
THE SOURCE OF THE GEMINIDS
REVEALED

It's the unlikely object responsible for this month's Geminid meteor shower, but relatively little is known about it. Now the enigmatic asteroid is starting to give up its secrets, as **Will Gater** discovers

MARK GARLICK

Following the clues: by taking a closer look at Phaethon, scientists are hoping to discover how the Geminids are created

▲ **Winter glory: the Geminid meteor shower is a highlight of the December night sky**

This month, Earth will sail through a stream of dusty debris scattered throughout the Solar System. As it does so, these tiny grains will vaporise in our atmosphere creating a shower of meteors – shooting stars – known as the 'Geminids'. Meteors and meteor showers aren't unusual but the story of the Geminids and, in particular, the object that creates them is.

Every flash of a Geminid flitting across the night sky marks the end of a journey whose beginnings are shrouded in mystery. But under the scrutiny of some of the world's most powerful telescopes and orbiting observatories, new clues are emerging about the origin of the Geminids as the enigmatic wanderer implicated in the birth of this celestial show – an object known as '3200 Phaethon' – is uncovered in ever more detail. To understand why it's so interesting, one need only look at what makes Phaethon so different.

"The puzzle started a long time ago with the Geminids meteor stream," says Professor David Jewitt – a planetary scientist and expert on Phaethon – from the University of California, Los Angeles. "Whereas most meteor streams consist of particles released from comets, the Geminids had no known parent, despite people having looked for one."

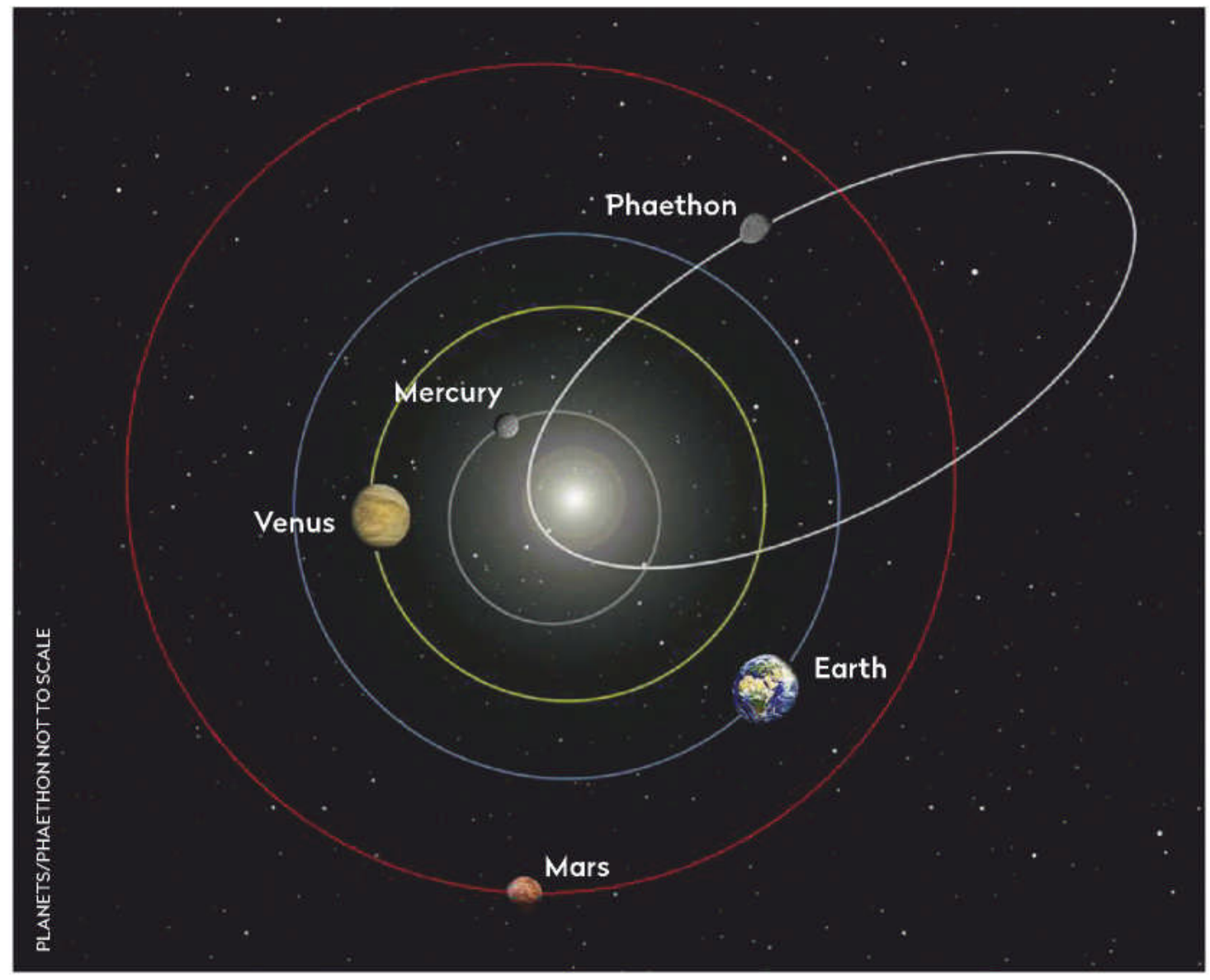
Then, in the early 1980s the Infrared Astronomical Satellite (IRAS) spotted a new asteroid, Phaethon. Its path around the Sun appeared to align with the clouds of interplanetary material responsible for the Geminid meteor shower.

The IRAS discovery brought with it a slew of fresh questions, however. "The new puzzle, and the one we are still working on, is that Phaethon is an asteroid not a comet. How can an asteroid produce the Geminid meteor stream?" says Jewitt.

Finding a connection

Early studies tried, in vain, to catch Phaethon behaving like a comet, ejecting dusty material into space. Yet the asteroid seemed inactive. "Then, one day my wife, Jing Li, suggested that we should try to look at Phaethon near perihelion," says Jewitt. Perihelion is the point in an object's orbit where it's nearest the Sun, and for Phaethon that is a blisteringly close 21 million km from our star. "Most telescopes can't look there, but Jing is a solar astronomer and she knew all about the telescopes

▼ **Hot pursuit: scientists observed Phaethon as its orbit took it close to the Sun's searing heat**



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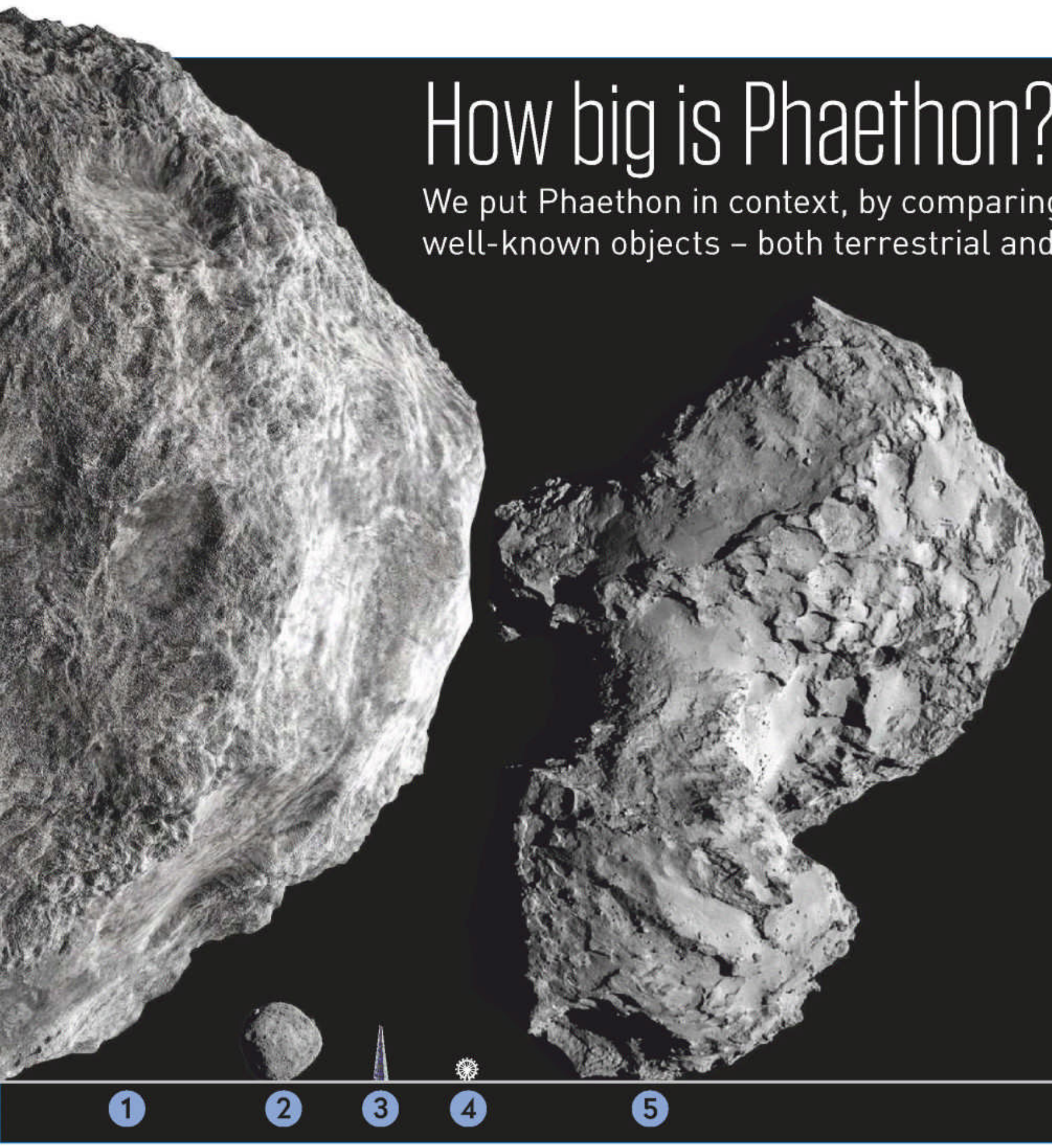
How big is Phaethon?

We put Phaethon in context, by comparing its size to some well-known objects – both terrestrial and celestial



1. **Phaethon – 6km (diameter)**
2. **Bennu – asteroid currently being investigated by NASA's OSIRIS-REx sample-return mission: 500m (diameter)**
3. **The Shard – the tallest building in the UK, overlooking the River Thames: 309.6m (height)**
4. **The London Eye – giant ferris wheel situated on London's South Bank: 135m (height)**
5. **Comet 67P – icy body visited by ESA's Rosetta mission: 4.34km (longest side)**
6. **Ceres – dwarf planet lurking in the main asteroid belt between Mars and Jupiter: 945km (diameter)**

on the STEREO spacecraft that are designed to point into the Sun," adds Jewitt.

Sure enough, when STEREO's images were analysed they showed the little asteroid increasing in brightness as it faced the onslaught of the Sun's heat. This was not the behaviour of an icy object – akin to a comet – warming as it approached our star, though. Phaethon was being baked at more than 700°C. At those temperatures any ice would be long gone. Instead, astronomers argued the surface of Phaethon was emitting grains into space as it dried and cracked in the searing heat.

In this unusual process, though, lay yet another mystery. Researchers were able to work out the quantity of dust being shed by Phaethon during its close swoop into the Sun's inner realm; it was nowhere near what's required to explain the amount of dust in the Geminid stream.

To explore what was going on, the astronomers used the Hubble Space Telescope to observe Phaethon as it was passing by Earth in 2017. "We wondered if Phaethon could be active away from perihelion as well, but just launching big particles that would be hard to see in most telescopes," recalls Jewitt.

Hubble didn't see anything however. That in itself said something important about the way Phaethon may have produced the Geminid meteoroid stream. "What it means is that the mass loss from Phaethon cannot be in steady state," explains Jewitt. "We need about 700kg/s to supply the Geminids but the STEREO observations gives us only 3kg/s. We need more than one hundred times as much, but [Hubble] shows that this is not happening. So we conclude that Phaethon didn't produce the Geminids in a steady way, but perhaps impulsively as a result of some disruptive event in the last few thousand years."

Collision course?

A 'disruptive event' might be a collision with another object or an explosion on Phaethon caused by buried ice sublimating. However, Jewitt suggests these scenarios are unlikely due to the emptiness of space and the anticipated high temperature of the asteroid.

"Other people, and I'm one of them, note that the rotation period of Phaethon (3.6 hours) is very close to the period at which gravity would be unable to hold the body together," says Jewitt. "So maybe it shed some material because it was spinning too ▸

How to observe the GEMINIDS

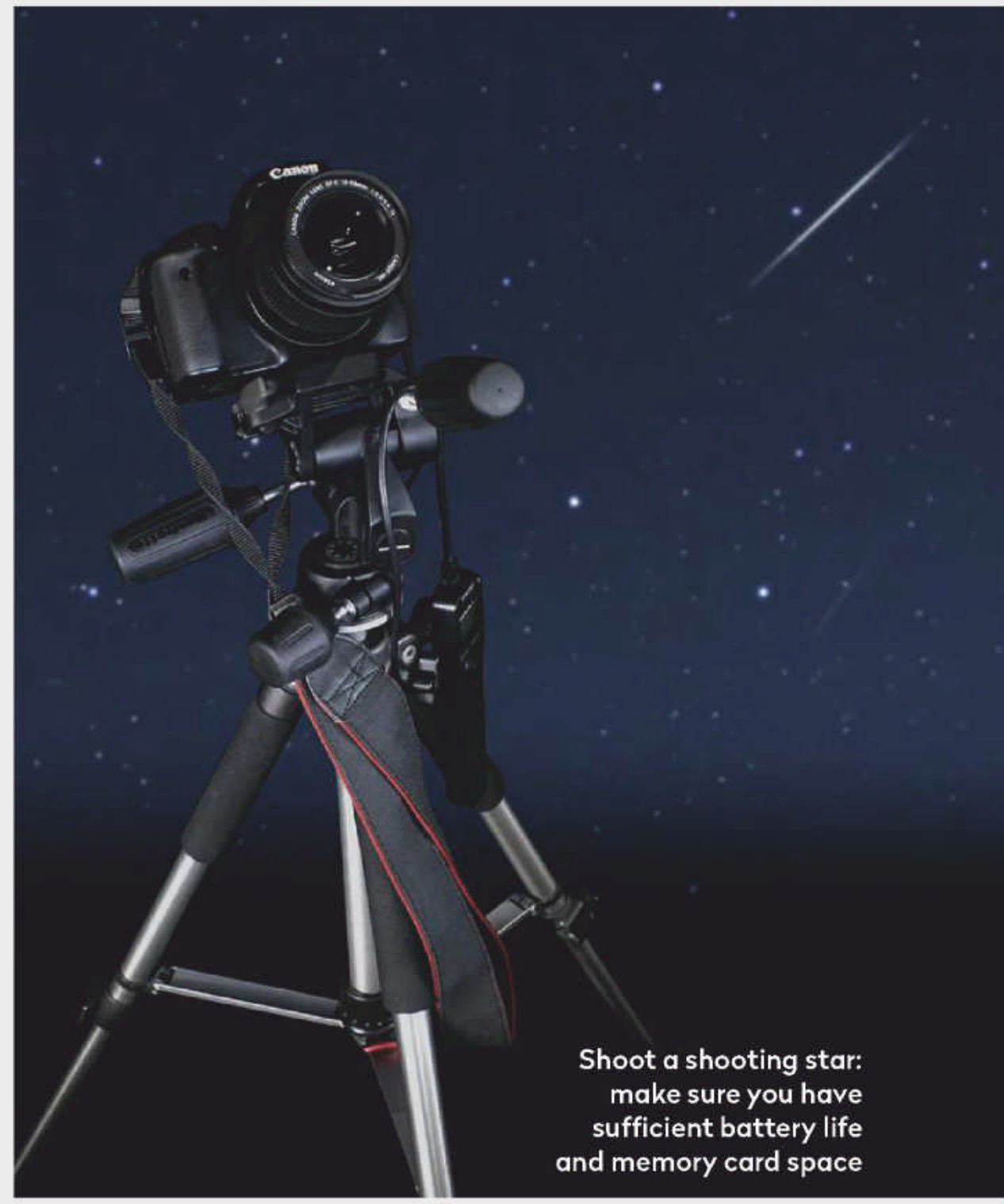
You can watch Phaethon's meteor shower, the Geminids, for yourself

The Geminids the meteor shower Phaethon's debris stream creates peaks on the nights of 13 and 14 December. This year's shower will be washed out by a bright gibbous Moon, hiding fainter meteors. It's still worth taking a look, but it's best to be realistic about how many you'll see.

▶ Is it a Geminid?
You can confirm you've seen a Geminid by tracing its path back to the shower's 'radiant', in the constellation Gemini.

▶ Where to look
You can look anywhere in the sky but avoid staring towards the radiant the Moon will be nearby and meteor trails will be short. The area of sky opposite the Moon might be a good place to focus your attention.

▶ Capture a Geminid with a DSLR camera
Imaging meteors can be deceptively hard, but for the best results use a wide, fast lens, a mid range ISO and a tripod. Repeatedly take exposures of about 10 30 seconds in length until a meteor flits across your field of view which might take a while. Ensure you have plenty of battery life and memory card space too.



Shoot a shooting star: make sure you have sufficient battery life and memory card space

▸ fast." That theory has its pitfalls too, though. "The problem is that we need this event to have occurred recently and the implication is that we are just lucky to be on-scene at the right time to see the consequences," explains Jewitt. "Reasonable people argue that appealing to this kind of luck is a step too far. I tend to agree with that."

Cracking the Geminid code

While it remains unclear what exactly went on to scatter the Geminid meteorid stream into space, researchers continue to examine what Phaethon is made of and where it might have originated – information that could illuminate the enduring enigma of the Geminids.

For Teddy Kareta, a graduate student at the University of Arizona, trying to understand Phaethon's make-up has been a key aspect of his PhD research. He recently used telescopes in Arizona and Hawaii to capture spectra of Phaethon – essentially a series of chemical fingerprints that are hidden in the light from the asteroid.

Those fingerprints need to be decoded, and the way Kareta and his fellow researchers intend to do that is by baking meteorites to examine how their spectra match up to the signatures in Phaethon's glow.

"When we started trying to interpret our observations of Phaethon, we realised that most previous experiments that heated meteorites to high temperatures, to compare to telescopic measurements, simply didn't get hot enough to be a great comparison to Phaethon. The options were to give up and say that we need better data, or build a vacuum heating chamber in the basement of our building," recalls Kareta.

The researchers did the latter and, at the time of writing, they are now preparing the apparatus for its first experimental run. "The general idea is that we grind up a meteorite, put it inside the heating chamber, pump all the air out, and then heat it up and cool it down over and over to replicate what being in an eccentric near-Sun orbit might be like," explains Kareta. "We're planning on heating up organic and water rich meteorites as the most likely analogues for Phaethon," he adds.

Research like Kareta's provides context for the understanding of Phaethon's origin. Some scientists think the asteroid could be a piece hewn off the much larger asteroid Pallas. Kareta himself isn't so sure. While Pallas's and Phaethon's spectra – the chemical signature of their surface in their light – are alike, the amounts of sunlight they reflect (a characteristic known as an object's 'albedo') are not. "When Phaethon moved into its current orbit and started getting really hot, its surface properties were cooked and changed as a result," explains Kareta.

Will Gater is an astronomy journalist and science presenter based in the UK.

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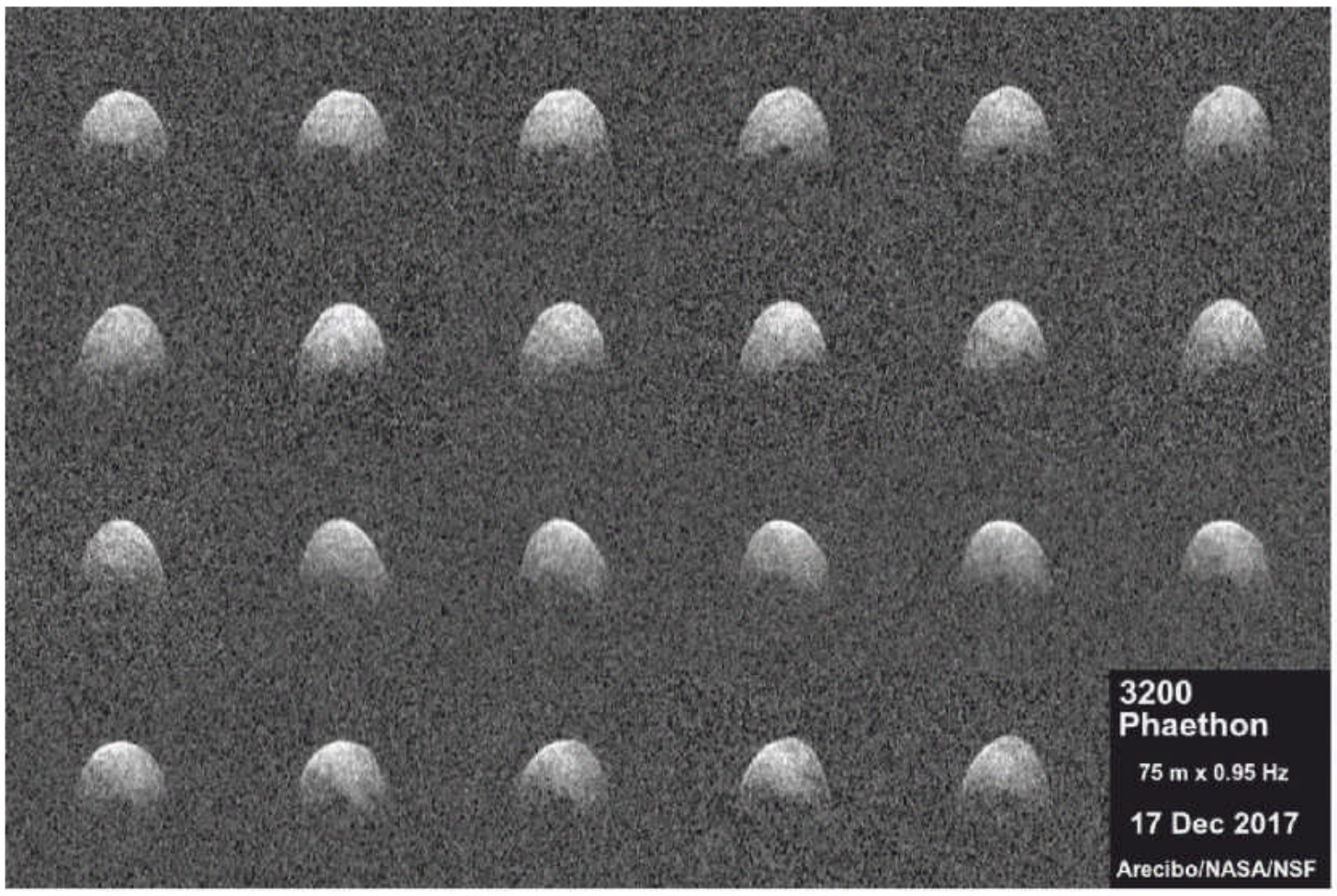
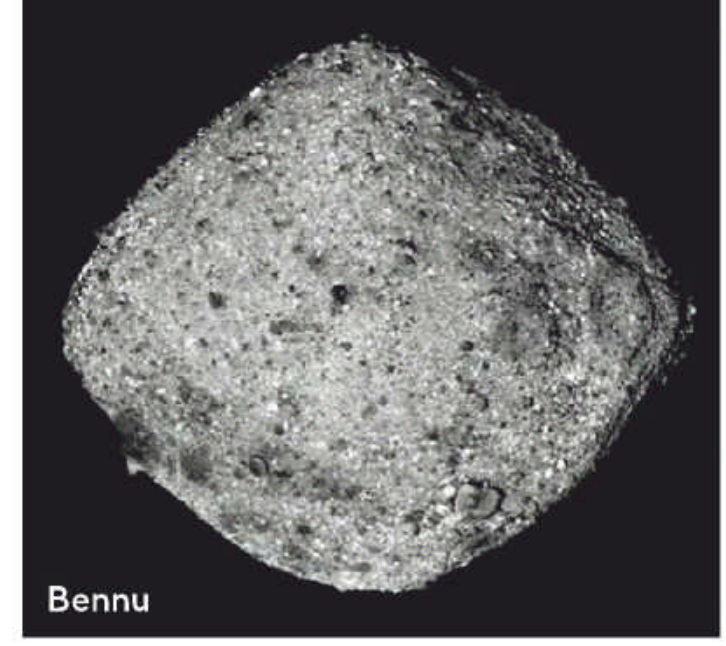
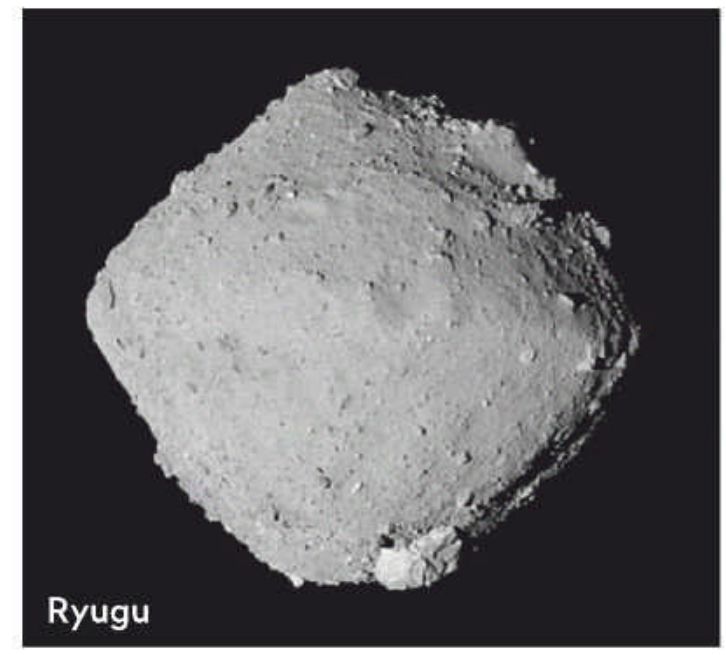






▲ Taking shape: the Arecibo radio telescope images of Phaethon reveal it as roughly spherical. It's now believed to be similar in shape to asteroids Bennu and Ryugu (right)

"When you cook a meteorite in the lab, the spectra and albedo both change, so we think it's hard to explain Phaethon as just being a cooked fragment of Pallas."

While Kareta and his colleagues' research works to build a picture of Phaethon's composition, other teams have been collecting actual images of the asteroid to examine its shape and size.

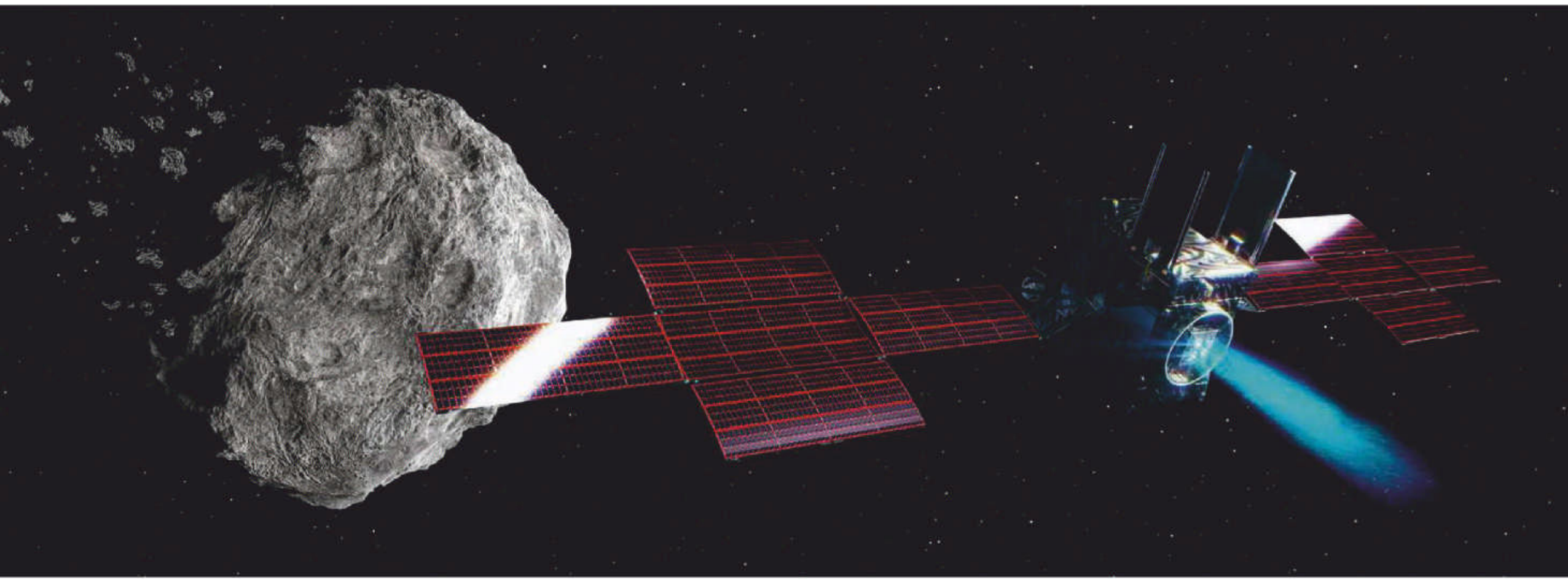
As Phaethon was swinging by Earth in December 2017, astronomers using the Arecibo radio telescope in Puerto Rico were bouncing radio waves off the asteroid to create a radar image of it. "We find that Phaethon is roughly spherical in shape and rather non-descript," says Dr Patrick Taylor, from the Lunar and Planetary Institute in Texas, who led the team using Arecibo.

"From the variation in signal strength in the radar images, we can hypothesise that some of the features are a large crater at the low latitudes of Phaethon and possibly a large boulder," he explains.

"We believe Phaethon has a shape very similar to asteroids Bennu and Ryugu, currently being visited by the OSIRIS-REx and Hayabusa2 spacecraft, but much, much larger."

Following these radar glimpses, scientists should soon get even better pictures of Phaethon. The Japanese space agency, JAXA, hopes to launch a mission – named DESTINY+ – to the asteroid in 2022. It'll be equipped with a range of imaging cameras and scientific instruments to examine Phaethon, and it could help answer some of the big questions that remain about this intriguing object. For Teddy Kareta, the opportunity to finally see the asteroid's surface up-close is a thrilling prospect. "For decades, Phaethon has been emblematic of everything we don't know about asteroids, comets, and everything in between," he says. "[It] is at the centre of one of the great mysteries of the inner Solar System, and I'm just stoked that we're gonna go and take a look."

▼ Getting closer: JAXA's DESTINY+ mission, scheduled for launch in 2022, will make a detailed study of Phaethon



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MYSTERY mountains of VENUS

Paul G Abel investigates enigmatic Venus and the unsolved puzzle of its fabled Himalayan peaks

IGOR FILONENKO/ALAMY STOCK PHOTO

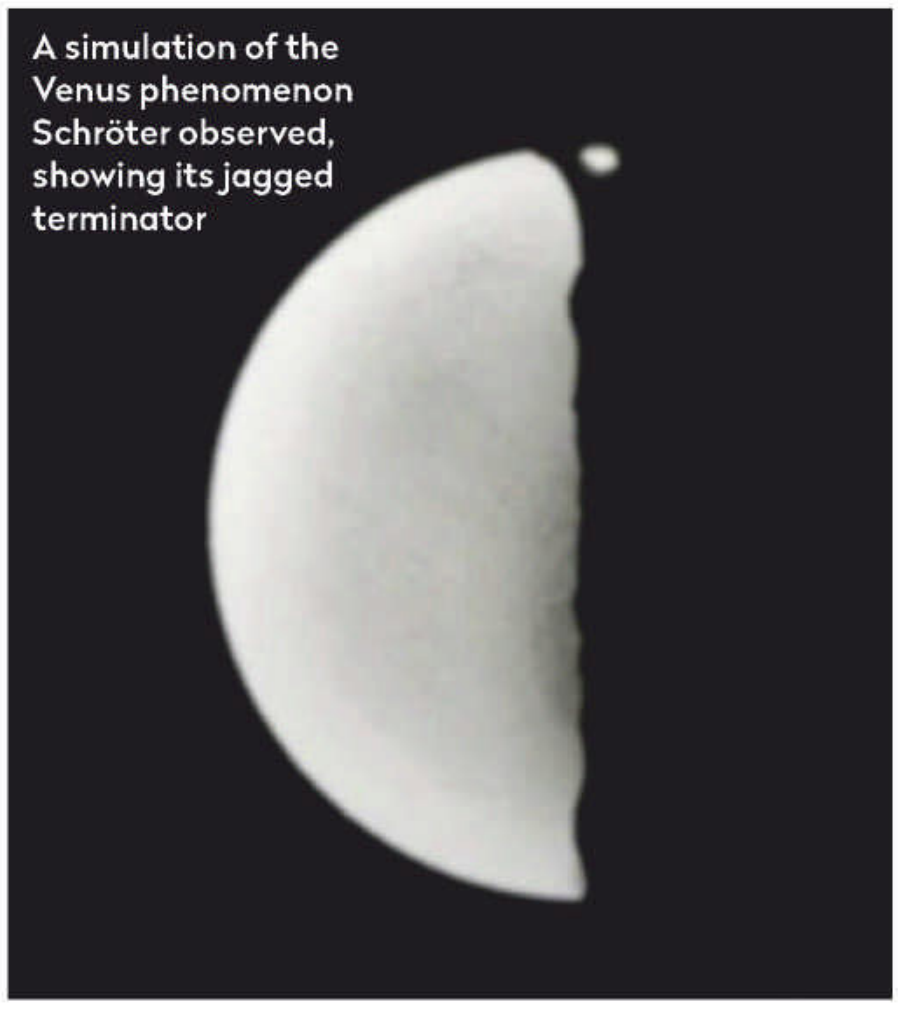
There's evidence of volcanoes under the dense clouds of Venus, but how active are they?

New approach: the phases of Venus convinced Galileo that the planet orbited the Sun

Have you noticed that the bright beacon of Venus has dominated the winter evening sky recently? For the past few years the planet has been poorly placed for observation, but over the coming months it will be an excellent target for amateurs. The last decade has been an exciting one for planetary science as space missions have revealed some tremendous discoveries about the planets in our Solar System. Yet Venus, the closest planet to Earth, stubbornly refuses to reveal its secrets.

Long since known as the planet of mystery, Venus has tantalised astronomers for centuries. Trying to peer through the ever-present clouds to learn about the baking world beneath has proved to be both challenging and frustrating. In spite of that, some early amateur astronomers made observations and formed theories that now seem strangely prescient. Their ideas are largely forgotten, yet there seems to be a nugget of truth in one enduring mystery from the 18th century – the supposed sightings of the Himalayas of Venus.

As far as we know, Galileo was the first person to turn a telescope towards Venus, in the winter of



A simulation of the Venus phenomenon Schröter observed, showing its jagged terminator

ROGER HUTCHINSON, PAUL ABEL X 2, SPUTNIK/SCIENCE PHOTO LIBRARY

There seems to be a nugget of truth in one enduring mystery from the 18th century – the supposed sightings of the Himalayas of Venus

1609–10. Although his telescope only had a power of x30 (less than a pair of modern binoculars), what he saw marked the beginning of the end for the old Earth-centred model of the Solar System. As he followed Venus, he noticed that the planet had phases ranging from full to a thin crescent – a phenomena that could only occur if Venus orbited the Sun.

As telescopes became more refined, the planets slowly gave up their secrets: the rings of Saturn were revealed, along with the ice caps of Mars. Yet Venus showed little surface detail except for some vague elusive streaks. In 1698, Christiaan Huygens was the first to realise that the planet had a thick impenetrable atmosphere that prevented astronomers from seeing anything.

Light on the night side

Yet interest in Venus did not diminish, and in particular the German astronomer Johann Hieronymus Schröter observed the planet in great detail. At about five in the evening on 28 December 1789, Schröter turned his 6.5-inch reflector towards Venus. What he saw was quite unexpected.

The seeing was good and Venus appeared nearly 50 per cent illuminated. The terminator appeared somewhat jagged, but it was the southern pole that caught his attention. Here, the southern cusp appeared rounded or blunt, but even more startling was the appearance of tiny specks of light on the night side of the southern pole.

Schröter had observed similar things on the Moon – the tops of high mountains catching the Sun's rays while the rest lay in shadow was a familiar sight – and he wondered: was he seeing the top of a vast mountain piercing the Venusian clouds? He

Spotting visual anomalies on Venus

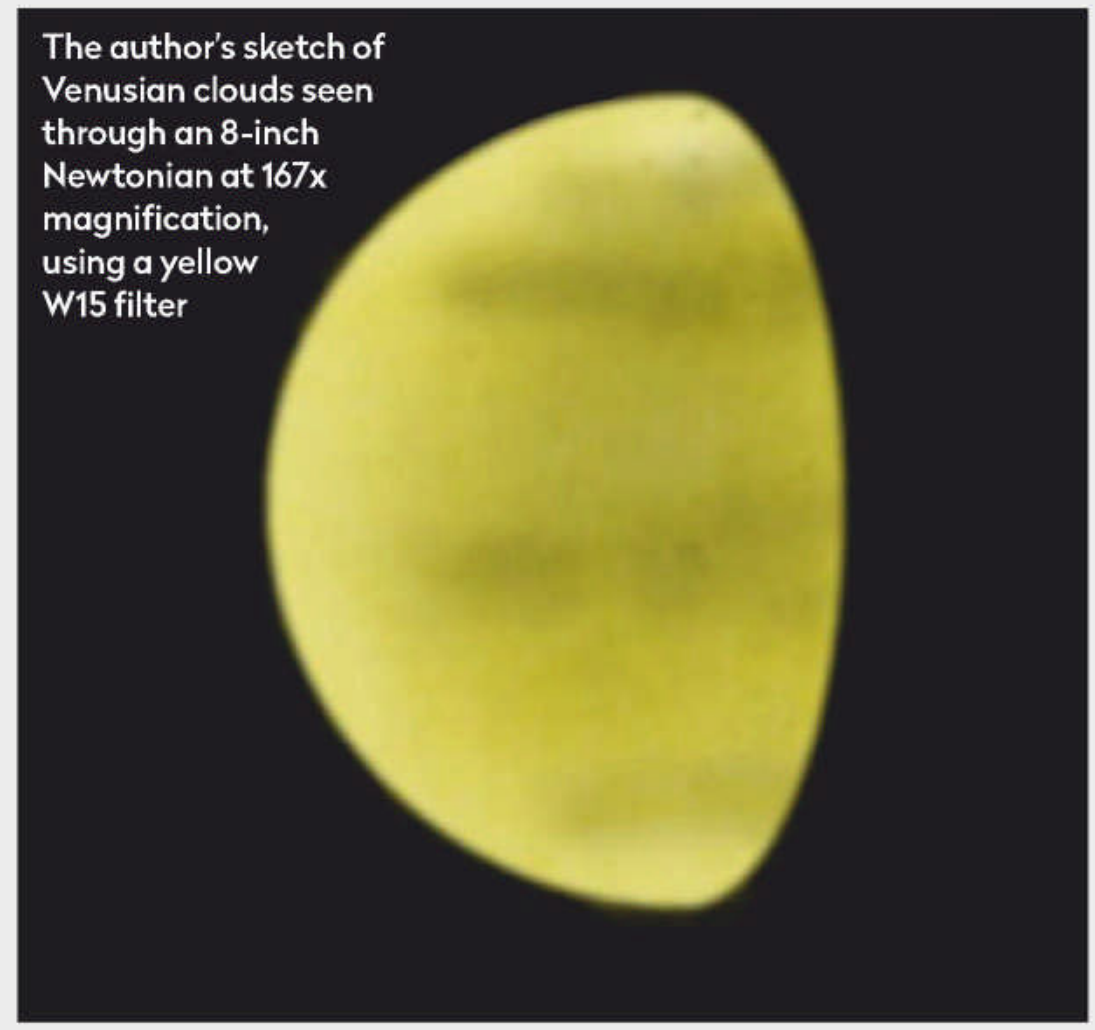
How to get the best observations of our mysterious neighbour

Visual observers can help by looking for evidence of any visual anomalies that might support evidence of changes in the Venusian atmosphere. Visually, Venus can be a challenge, but there are a number of techniques that help. Try to observe Venus in a bright twilight sky when the Sun's just set. This will help reduce the glare from the disc. A yellow W15 filter will also help clean the image.

One thing to keep an eye on is the terminator, especially as the planet approaches dichotomy (50 per cent illumination), which occurs around 26 March 2020. Usually the terminator appears to be a smooth line. Check this is still the case, or whether it appears somewhat jagged and irregular.

Another phenomenon to watch out for is the Schröter effect. Venus reaches theoretical dichotomy on 26 March, but actual observed dichotomy is likely to occur a few days before this, due to light being scattered by the thick atmosphere. The effect is more pronounced in a blue filter. If it occurs more than six days before theoretical dichotomy then this might be an indication that something unusual may be happening in the atmosphere. Keep an eye out too for bright spots or very dark markings in the clouds, particularly if they are persistent.

For more information about how your observations can contribute to the scientific study of Venus, visit the British Astronomical Association's Mercury and Venus section at **britastro.org/section_front/18**.



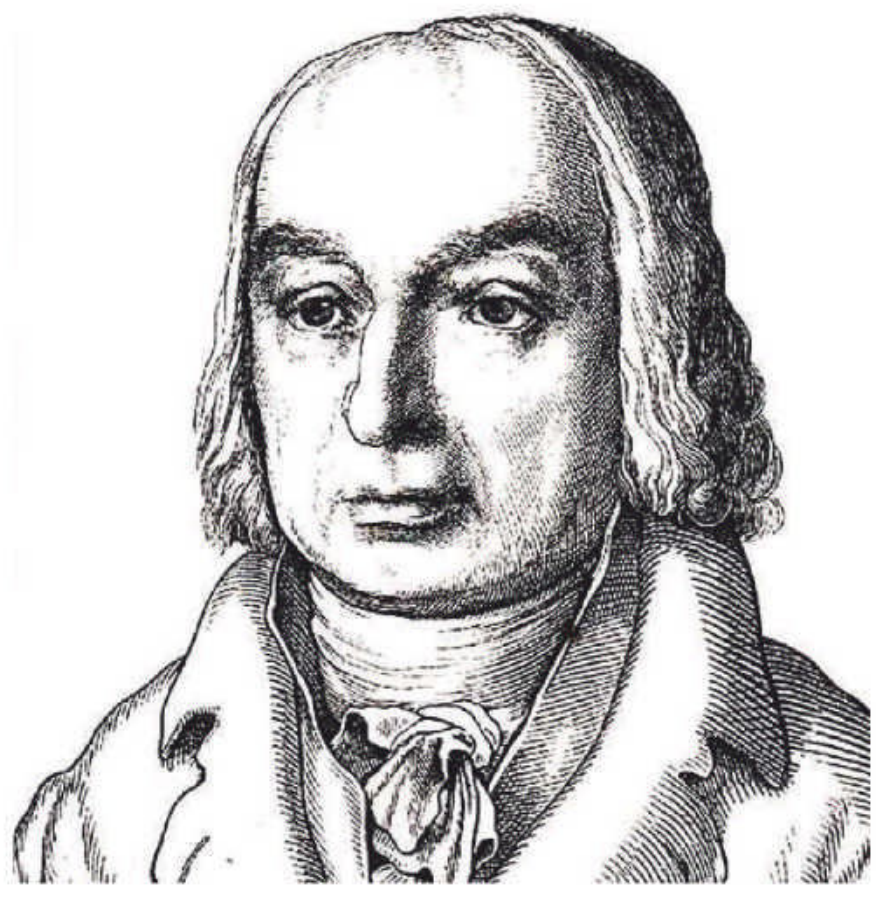
The author's sketch of Venusian clouds seen through an 8-inch Newtonian at 167x magnification, using a yellow W15 filter

estimated such a mountain would need to be 16-30km high, overshadowing the highest mountains here on Earth. He had a similar view on 31 January 1790 and three more times in December 1791.

William Herschel (who had in fact made Schröter's telescope) was somewhat sceptical, not having made any such observations himself. This was not the only account, however.

In 1813 and 1814 the German observer Franz von Paula Gruithuisen noted the caps seemed to be particularly brilliant. He also observed spots and made comparisons with the polar ice caps on Mars, which looked very similar. In 1878 the French astronomer Étienne Léopold Trouvelot observed 'sparkling stars' at the base of the southern polar regions, which again were interpreted as the peaks of the 'Venusian Himalayas'. Although the reports of bright, detached peaks vanished by the end of the 19th century, there are still a number of 20th-century observations showing Venus with a deformed terminator or blunted caps.

With the dawning of the Space Age, there was much speculation about what our robotic emissaries would reveal about Venus. Would we discover a ►



► Seeing the light: Franz von Paula Gruithuisen (right) and Étienne Léopold Trouvelot (far right) noted the bright caps on Venus

▸ tropical paradise covered in oceans, or would the planet be an oil prospector's dream, rich with oceans of hydrocarbons? These were some of the competing theories about what might lie below the Venusian cloud tops.

On 14 December 1962, NASA's Mariner 2 passed within 34,773km of Venus and revealed a desolate world with a surface temperature of 500°C – hot enough to melt lead. The Russian Venera probes provided tantalising images of the surface, showing a volcanic landscape under a dull yellow sky. Further missions started to reveal some surprising results – lightning was detected in the sulphuric acid clouds and violent winds dominated the upper atmosphere. In 1990, NASA's Magellan probe used radar to pierce the clouds and map the surface. Those striking images revealed a surface dominated by vast shield volcanoes and strange geological faults.

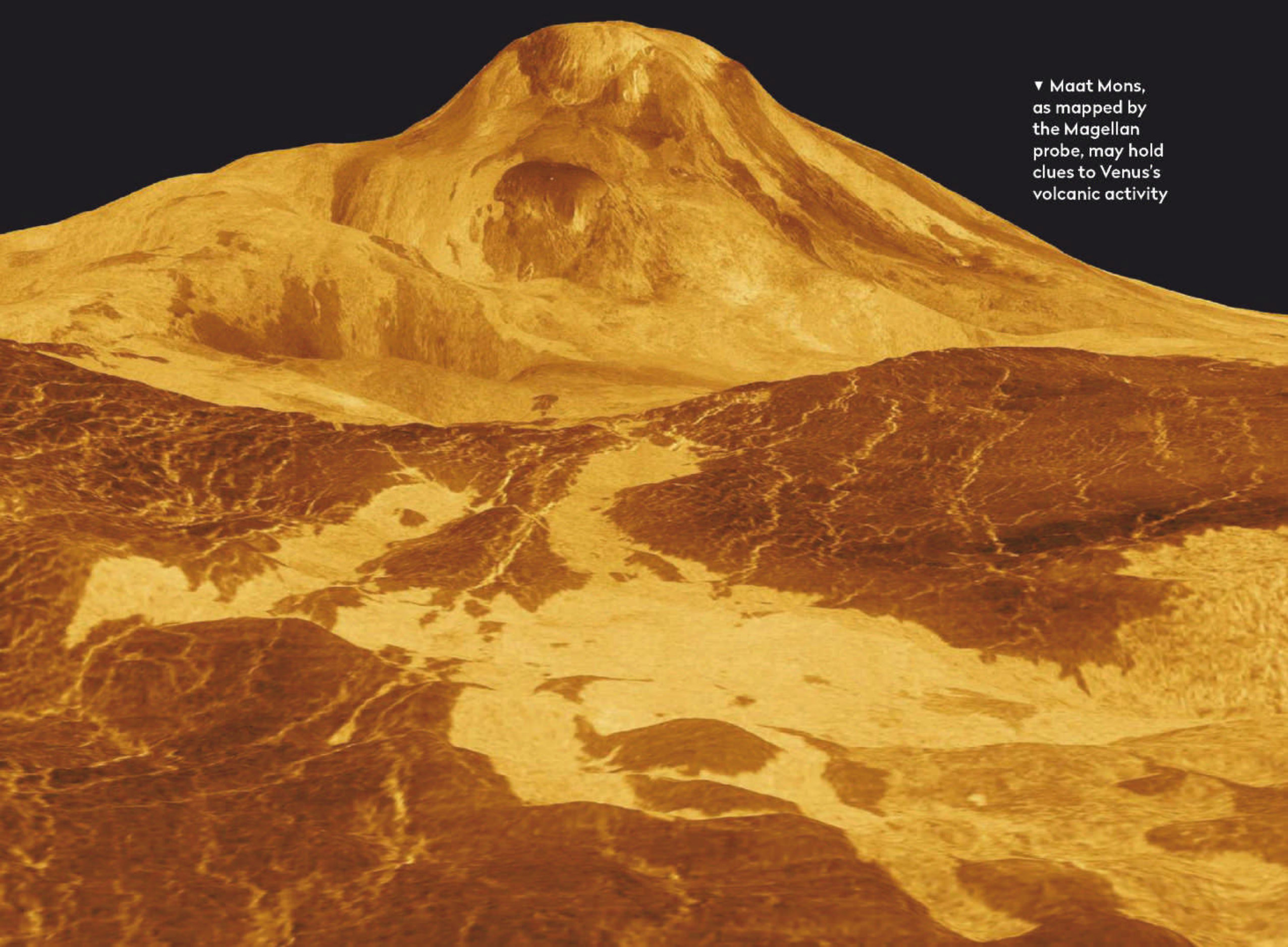
Perhaps the biggest mystery was the age of the surface. On the Moon and Mars, craters show that some parts of the surface are much older than others, and yet the surface of Venus appears to be all the same age. Could there have been some violent resurfacing in the distant past?

During the 1970s and '80s, NASA's Pioneer Venus spacecraft recorded large variations in sulphur dioxide levels in Venus's atmosphere. This gas is usually a by-product of volcanic activity and, taken with the Magellan data, led many scientists to believe that Venus is probably a volcanically active world – we just haven't caught it in the act yet.

▲ A full disc radar image of Venus, captured by NASA's Magellan spacecraft

Amateur imaging needed

This brings us to amateur astronomers today. In 2017, Australian amateur astronomers Phil Miles and Anthony Wesley successfully imaged the night

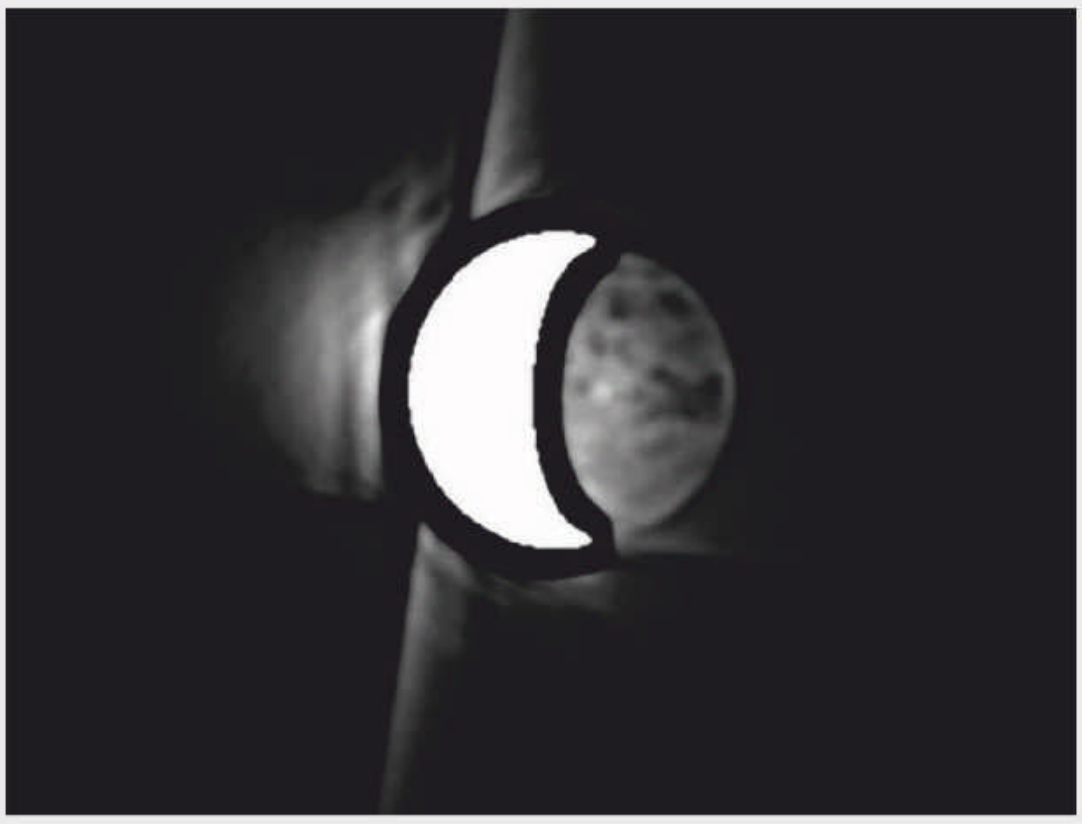


▼ Maat Mons, as mapped by the Magellan probe, may hold clues to Venus's volcanic activity

NASA/JPL X 2, © PHIL MILES/RUBYVALE QLD AUSTRALIA, PHIL MILES/ANTHONY WESLEY, MARK GARLICK

Capturing Venus in infrared

Why astronomers are looking for volcanic activity on the planet's night side



▲ **Bright sparks: in 2017, small bright spots were observed on the night side of Venus (left), as captured by amateur astronomers Phil Miles and Anthony Wesley (pictured right) with their 508mm Newtonian telescope. These may be evidence of volcanic activity.**

Trying to search for active volcanoes on the surface of Venus is no easy task, but it is now within the means of amateur astronomy. The first requirement is a large aperture scope (at least 200mm). The next essential items are filters and cameras that allow you to image Venus in infrared. The surface of Venus is about 500°C and you're going to need to image the planet in the 1020nm band. You will need to find either a filter or camera in this range (or stack two separate filters together). Hotter regions should appear as brighter spots.

The faint images will require careful processing and you will need to take several images over the course of an evening to confirm any bright spots are genuine. The best time to start your search is when Venus is in the crescent stage, otherwise the sunlit clouds will wash out the faint nightside image. Venus becomes a crescent after 10 April 2020, so you should try and carry on as far as possible into inferior conjunction on 3 June.

For more information about the Venus night side project, see **www.astrogem.com.au/Venus/nightside**

side of Venus in infrared (see above). They captured the glowing surface and something else: small bright spots on the surface. Is it possible these spots are the smoking gun, images of active volcanoes?

"The bright spot Phil recorded in 2017 was very interesting and quite unexpected," says Anthony Wesley. "We're both very keen to image that region again next year and see if it appears the same or different." If it is the case that Miles and Wesley have indeed been the first people to capture active volcanoes on the surface, then this is an entirely new line of research that astronomers can pursue. We will of course need many more similar observations before we can be certain. That said, it does give the amateur a new purpose as we finally have the tools to peer beneath the Venusian clouds.

The Himalayas of Venus as recorded by Schröter and others were probably illusions caused by poor seeing, and yet these early attempts to glimpse beneath the clouds of our sister world seem to be in some small way commemorated by the possibility of active volcanoes on the surface of this enigmatic planet. As Venus returns to our evening skies, it would be quite fitting if it was an amateur astronomer who discovered them.

Paul G Abel is director of the British Astronomical Society's Mercury and Venus section

Amateur astronomers are being inspired to search for active volcanoes on Venus

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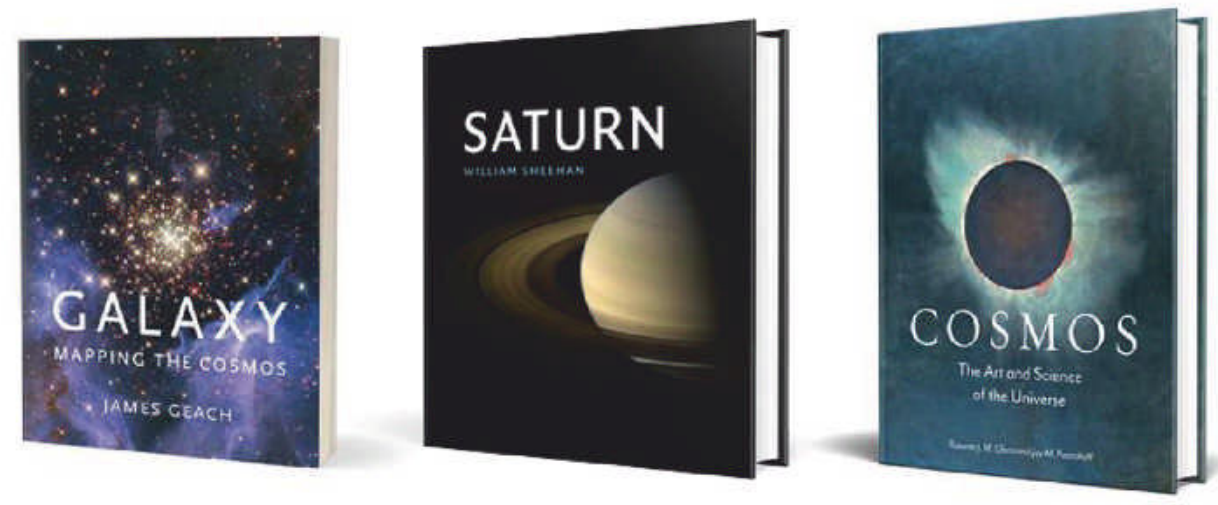

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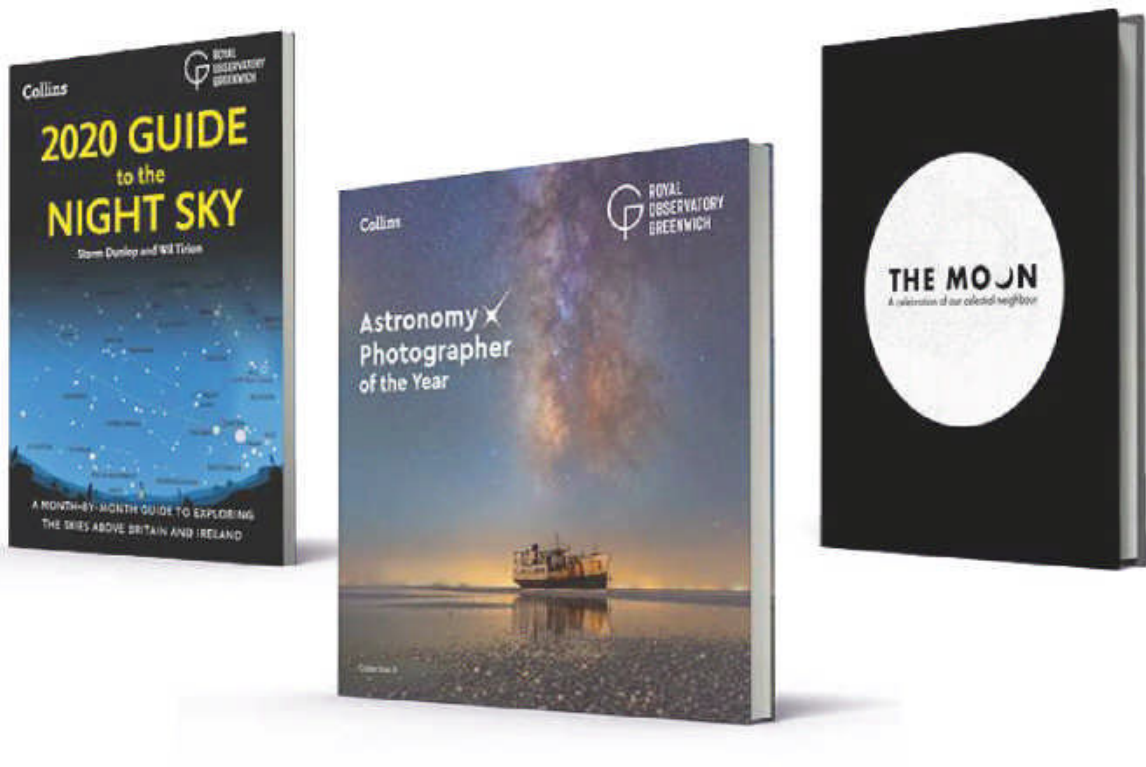

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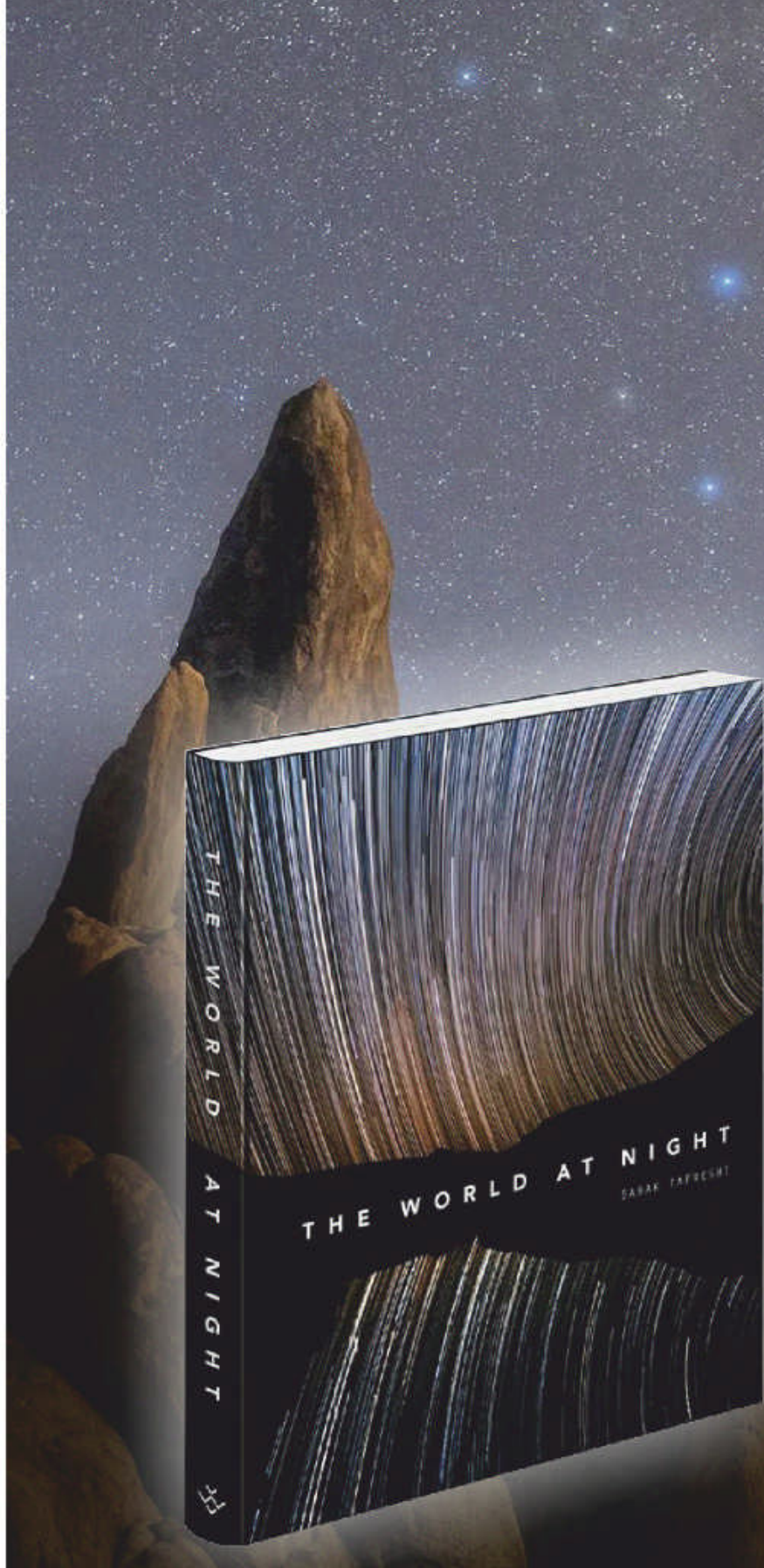

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Build an off-axis aperture mask

Construct an accessory for a reflector telescope to combat unwanted light

Are you the owner of a reflecting telescope? If so, this month's project – making an off-axis aperture mask – is for you. Masks are made from opaque material, with a hole cut in, and placed over your scope tube in order to reduce the amount of incoming light. An off-axis mask has its hole located away from the centre so any light misses the central obstruction and supporting structures, falling directly onto the primary mirror surface.

Making life easier

The effectiveness of these masks is debated among astronomers, but advocates point to three main advantages. Some objects, notably the Moon, appear bright when viewed through the eyepiece and this can feel uncomfortable if your eyes are dark-adapted. You could attach a neutral density filter, a 'Moon filter', to your eyepiece to absorb some light or observe from a brighter location, but a mask reduces the incoming light and relieves your eye. The resolving power of the scope will be adversely affected by a mask, but at low to medium magnifications, this might not concern you.

A second advantage deals with the effects of the vanes which hold a reflector's secondary mirror, which interfere with the image. Although attractive in photos, diffraction spikes may disturb observing. Light passing through an off-axis mask can produce clean views.

Finally, masks modify the scope's optics. The "exit pupil" is the diameter of the circular zone behind your scope through which all light rays pass. This appears as a bright disc when you look into the eyepiece. The diameter of your eye's pupil commonly varies between 1-7mm, with 5mm a typical maximum if you are middle aged. With a large aperture, short focal length scope, the exit pupil may be too large for your eye to take in. For example, a 12-inch (304mm) f/4.5 scope and 40mm eyepiece has an exit pupil of 9mm, so an eye with a 5mm pupil would take in just 30 per cent of available light. Reducing the aperture reduces the exit pupil, optimising your view and possibly making it easier to focus. An exit pupil size between 1-2mm is optimal for resolving detail (eg, observing double stars). A 6mm eyepiece in our example 12-inch scope produces a 1.3mm exit pupil, but its magnification is 225x which is unrealistic. Masking with a 125mm hole enables an 18mm eyepiece to create an exit pupil of 1.7mm with 75x magnification. The captured light is reduced to 17 per cent, but performance now equates to a 5-inch f/11 scope, which may be perfect for the task in hand.

You can input your scope and eyepiece details into our downloadable calculator (see below) for mask sizes. Some suggest the benefits of masks are negligible and more to do with perception. However, they are cheap and quick to make, so why not decide for yourself?

▲ **The completed mask is used to limit incoming light**

Mark Parrish is a bespoke designer. See more of his work on his website: buttondesign.co.uk

ALL PICTURES: MARK PARRISH

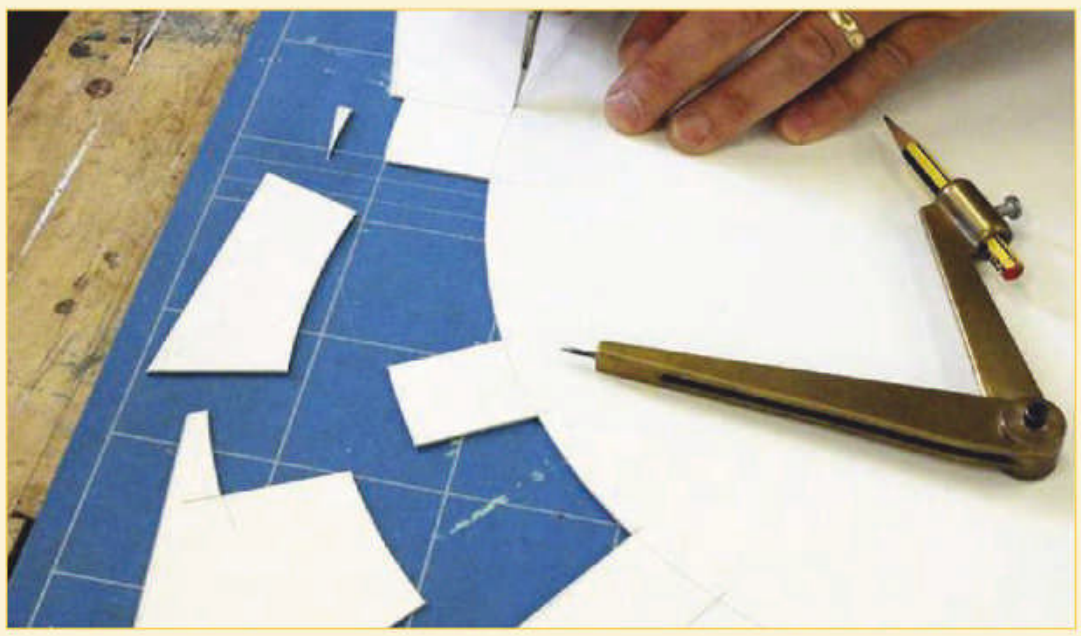
Tools and materials

- Marking out tools (ruler, compasses, pencil), a craft knife and cutting mat.
- Two or three sheets of stiff card (approximately A3, depending on scope size) preferably black, although it can be painted.
- Sticky tape, craft glue and Velcro.
- For the finish you will need some spray paint (if the card requires it), varnish or lacquer to make it moisture resistant and a white marker pen.

More ONLINE

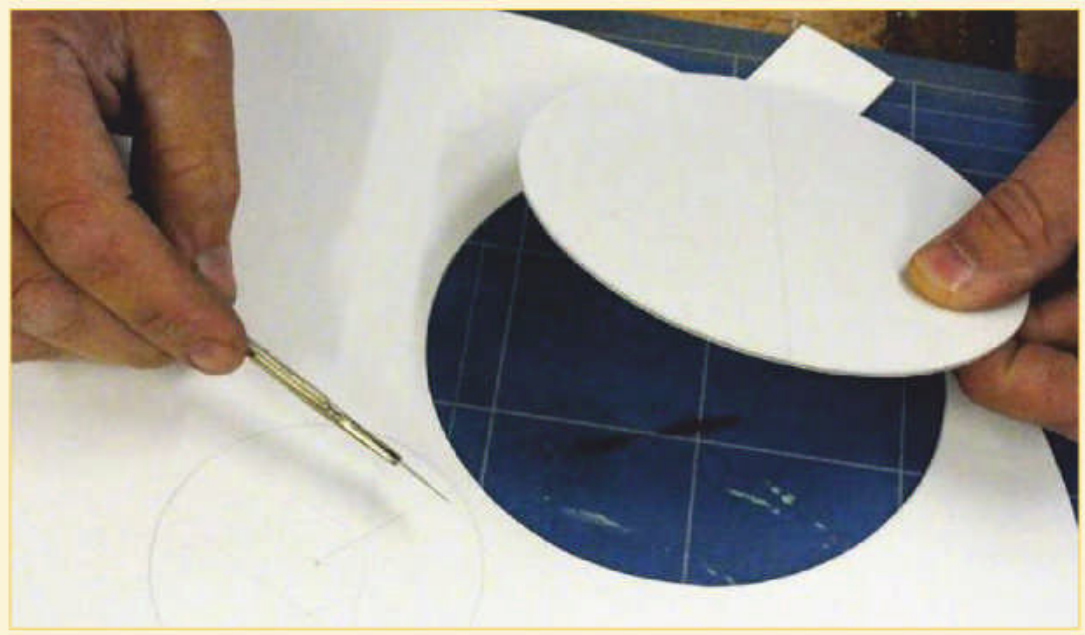
Download more photos and an off-axis mask size calculator. See page 5 for instructions

Step by step



Step 1

Measure the external diameter of your tube and use compasses to draw the circle. Cut it out leaving 40mm tabs every 75mm or so. Cut strips of card, about 40mm wide long enough to go around your tube at least twice (about 7x the diameter).

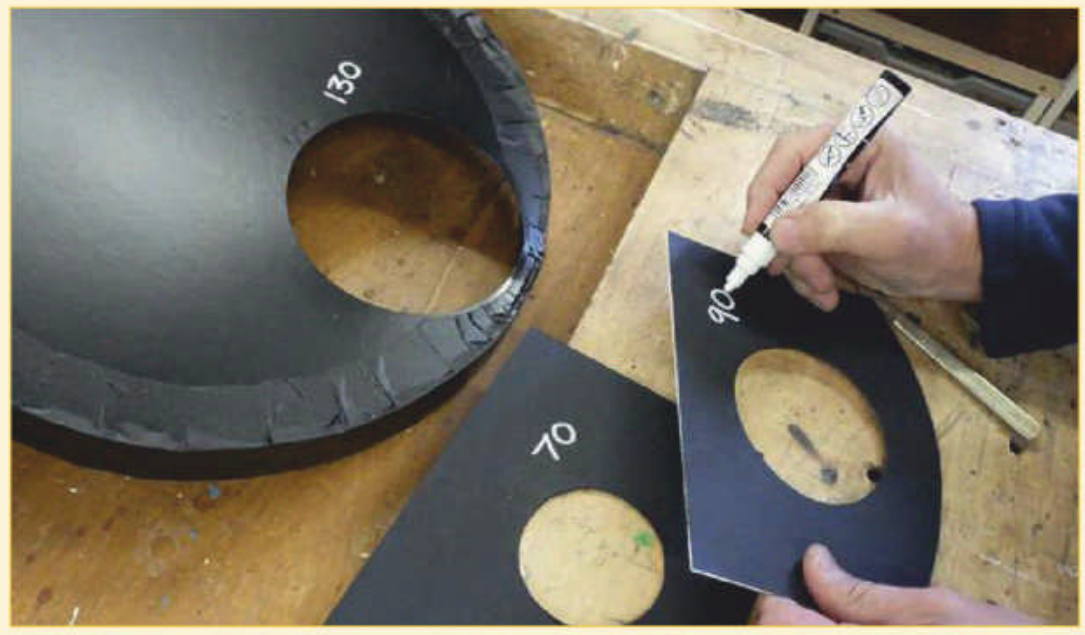


Step 2

Measure the minor axis of your secondary mirror and use the downloadable calculator (see page 5) to find the largest possible aperture for the mask hole that gives a clear unobstructed aperture. Carefully cut out this hole in the main disc.

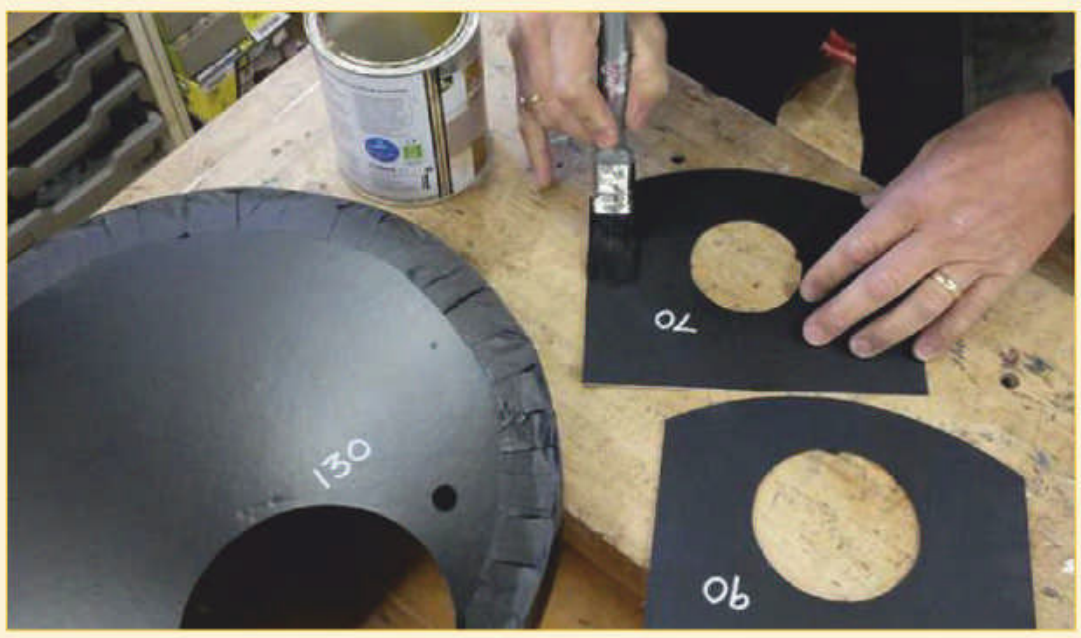
Step 3

Use tape to fasten a single layer of strips around the tube. Add the main disc, fold and carefully glue down the tabs to the strip. Add more layers of strips and tape to form a stiff ring and secure the tabs. When the glue is dry, take the mask off the tube.



Step 4

Use card off cuts to make additional reduced apertures to add to your mask. You can experiment with these by using the downloadable calculator (see Step 2). Paint card parts black if necessary. Label them with a white marker to indicate diameters.



Step 5

To make the card more rigid and provide some resistance to moisture, apply thin coats of lacquer or varnish. Don't use too much at once or the card may get soggy and distort. Once dry, Velcro dots can be applied to hold additional masks in place.

Step 6

When fitting it to the scope, turn the mask so the incoming light misses any vanes. If your scope has not cooled down it may be advantageous to have the hole in the lowest position, as warmer, swirly air tends to gather at the top of the tube.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Hot on the trail of comet 2I/Borisov

How to best locate and image this interstellar visitor and avoid unwanted image artefacts

Our first identified interstellar comet has been confirmed and 2I/Borisov (also known as C/2019 Q4 Borisov) is currently visible in UK skies. The good news is that it will be at its brightest mid-month but there is bad news too. At its brightest the comet is expected to be just mag. +15.3 and its track is dragging it south. From the UK, this is the last month it'll be visible.

Grabbing an image of the comet is a special thing to do, but thanks to that low brightness don't expect anything spectacular. 2I/Borisov is expected to appear between mag. +15.3 and +15.9 all month and is likely to record as a dot of light, possibly smudged by a tail.

Such a remarkable object, which has its origins beyond the gravitational influence of the Sun, deserves a bit of effort to capture. Brighter than mag. +16 it's well within the reach of modest amateur kit.

In order to assess whether you can record it, you'll need at least an equatorially tracked imaging setup. The exposure time will need to be sufficient to record down to at least mag. +16, but as comets are diffuse in nature, aiming lower is a good idea if you can. The comet will be low from UK latitudes during December, reaching a peak altitude above the southern horizon on 1 December of 23°. This is just before 06:00 UT and immediately before the end of astronomical darkness, so you'll need to pick it up earlier – say from 05:00 UT when it'll be slightly lower.

How the comet will look is unknown at the time of writing. If it's showing a tail, it will be easier to identify but if not, one technique for locating it in your images will be to use blink aligned images taken on different dates. If there's a dim object which appears to move between frames, this is a good candidate for 2I/Borisov.

One drawback of digital imaging is noise, or unwanted image artefacts, and these must be managed to get the blink technique to work. Hot pixels are classic culprits for looking like moving objects when frames are blinked. You must eliminate these before you try to find the comet. Hot pixels are easy to remove. The technique involves taking your shots of the comet using a set exposure; these are referred to as light frames. Then cover the front of the scope using its lens cap – this must be light fast – and repeat the same exposure. The resulting images, known as dark frames, will be black apart from the hot pixels.

Low level thermal background noise will also be present in the dark frames, so it's best to take a number of these, say 9-16, and average them together. This smooths (averages) the background noise in inverse proportion to the square root of the number of frames used; nine reduces the noise to one-third and so on.

Once you have your averaged dark frame it needs to be subtracted from each light frame to remove any hot pixels. It's important to maintain any camera settings and take the dark frames under the same temperature conditions as the light frames.

▸ *See page 46 for a chart of 2I/Borisov's position*

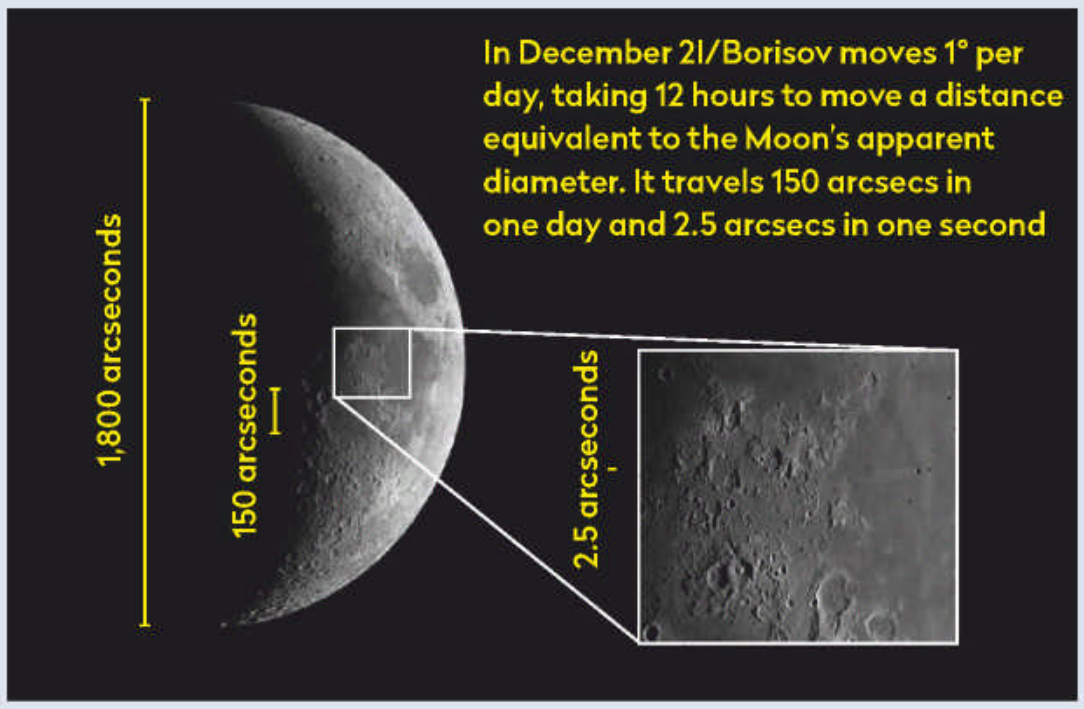
▲ On the move: images of comet 103P/Hartley, taken on the same night, reveal tiny movement relative to background stars

ALL PICTURES: PETE LAWRENCE

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

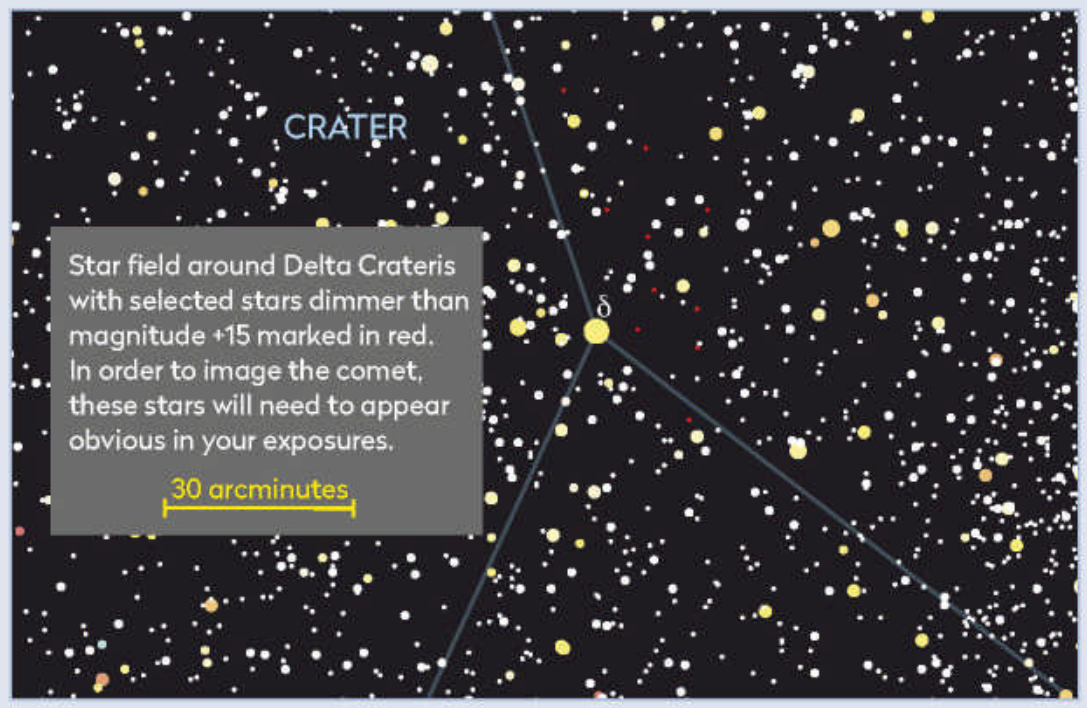
Recommended equipment: Telescope on an equatorial tracking mount, CCD or CMOS camera

✉ Send your images to:
gallery@skyatnightmagazine.com



STEP 1

Decide on your image scale. This is defined by the focal length of the optics attached to your camera. If you intend to manually locate the comet, cover a wider area first, say 2–3° across. Once located, consider a tighter field of view 30 arcminutes or smaller. Once you've set up ready for imaging, spend time getting the focus sharp.



STEP 2

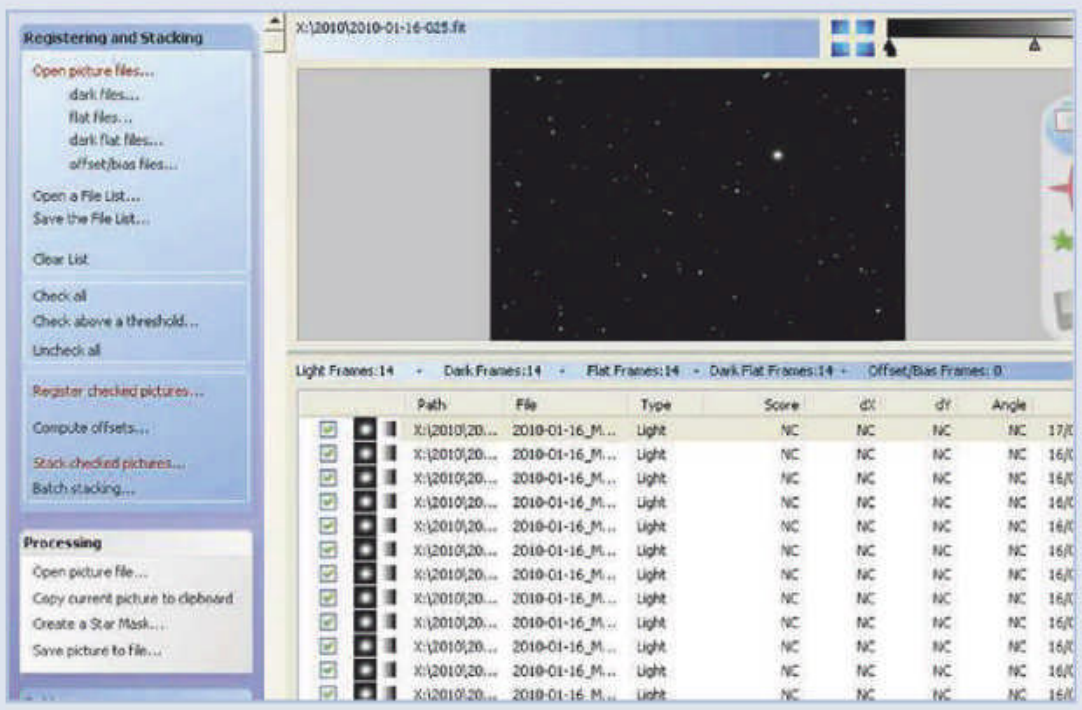
Ascertain whether your setup can record magnitudes down to the depth of the comet. During December, 2I/Borisov will also have a low altitude and this will affect the depth of your images. Choose a test exposure of say 60 seconds and evaluate how deep it goes. Our chart shows stars around the Delta (δ) Crateris down to mag. +15.5.

STEP 3

Comets move relative to the background stars. Equatorial tracking moves with the stars. It's best to use shortish exposures to capture the comet, in the range 30–60". Aim to take a number of these, say 20+. The amount of comet movement recorded will be affected by your image scale. Larger scales will show greater relative motion.

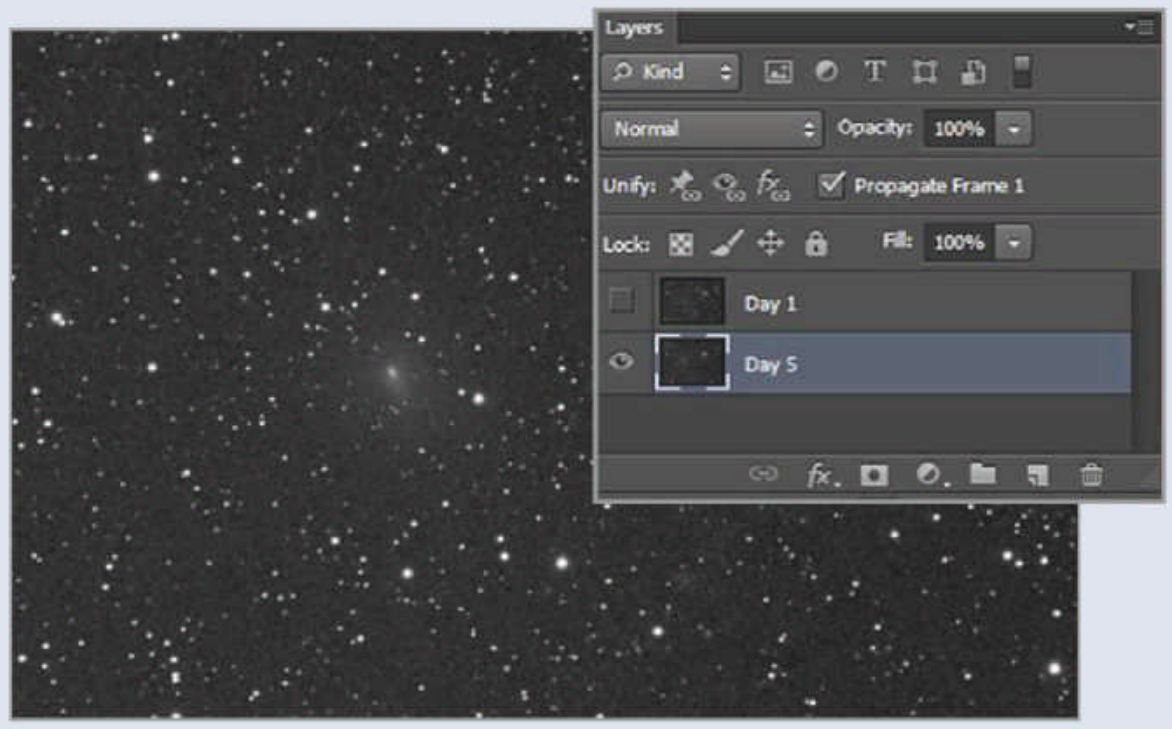
STEP 4

Once you've recorded your light frames, you should take calibration frames too. At the very least, dark frames (see main text) should be taken to calibrate each light frame. Use the same exposures for light and dark frames. You can also apply flat field correction to remove any unwanted dust or light path effects.



STEP 5

Once you've calibrated the light frames, you can choose how to work with them. Programs such as DeepSkyStacker (**deepskystacker.free.fr/english/index.html** freeware), APT (**ideiki.com/astro/Default.aspx** under £20) or PixInsight (**pixinsight.com/** £200) can help align and average your shots.



STEP 6

If you're using a wide image scale, if the shot goes deep enough to record the comet, try aligning the stars between two or more shots taken over several days. Blinking between the shots or, better still, animating them in a graphics editor, will show if you've captured it the comet's motion against the stars over the capture period.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

IIAPY Masterclass Removing twilight effects

How to overcome the drawbacks of planetary imaging at twilight and reap the benefits

The steadiness of the atmosphere is one of the biggest factors influencing success in planetary imaging. If you image when the seeing is good, your data will be less affected by the smearing and blurring effects of air at different densities chaotically moving above. Subsequently, your images will be richer in detail.

A neglected but rewarding time to image is around sunset, and just afterwards when the sky is in bright twilight. The wind dies down, the clouds dissipate, and a calmness reigns. Later on, the coldness cools the ground and convection currents worsen the seeing.

Although twilight imaging can have benefits, it can also create hurdles. Finding the planet in a bright sky can be one issue, especially if you can't align to use your Go-To system. Even if you find the planet, the wash of bright bluish light that partly drowns out the object can reduce the contrast between the planet and the background, making it hard to focus. The extra light will also increase the disc's brightness, requiring you to reduce the exposure. At sunset the light from the planet itself would have been reduced by a factor of 2.5x, leading to 1.6x the level of noise, or unwanted artefacts, in the final processed image. Using an infrared filter and a monochrome camera can help, by dimming the background more than the planet, allowing longer exposures without overexposing. If you stick with colour imaging, you'll need to gather more frames than normal to bring the image noise back down. Be careful not to set up too early, as later on, when the skies are still steady but have darkened a bit more, things will be easier.

Colour imaging in twilight will also produce a bluish wash over your processed image, upsetting the colour balance of the planet. It may be tempting to

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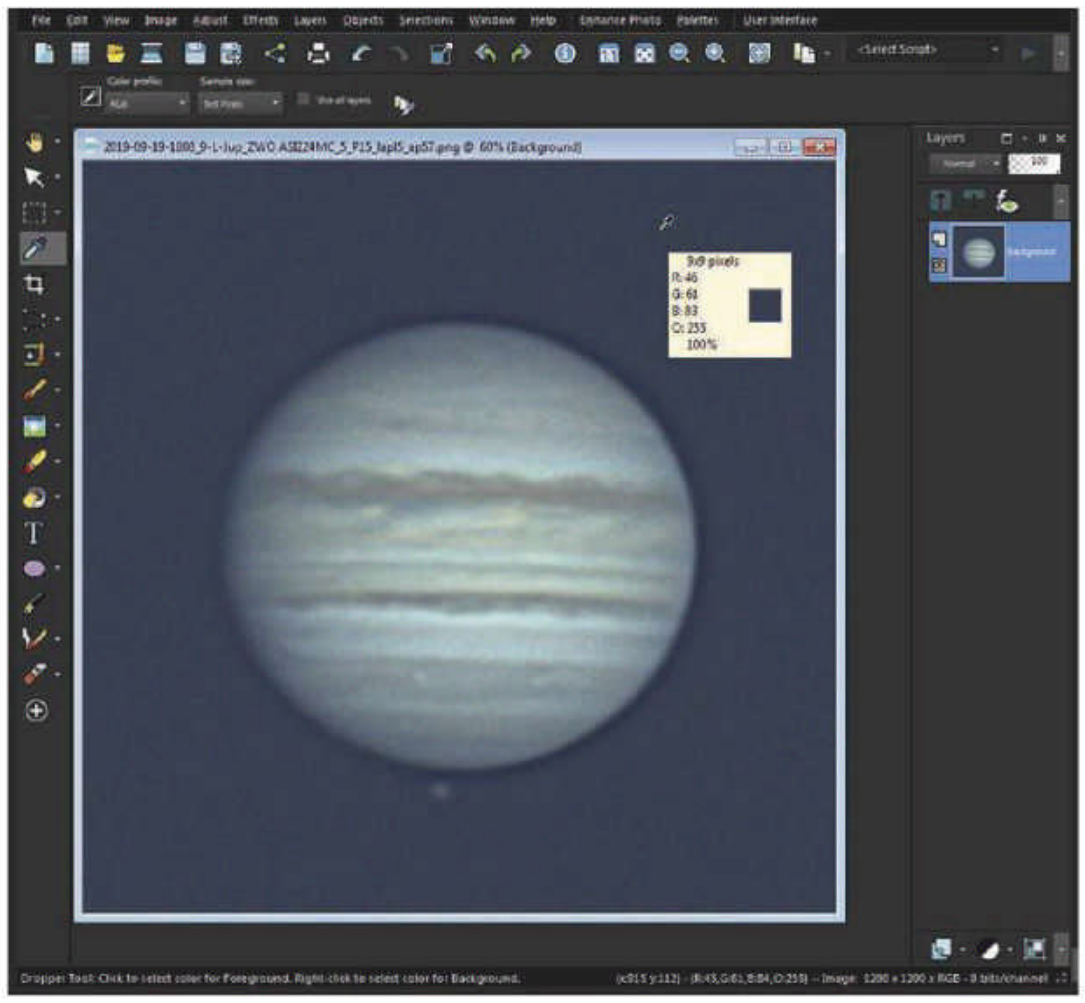
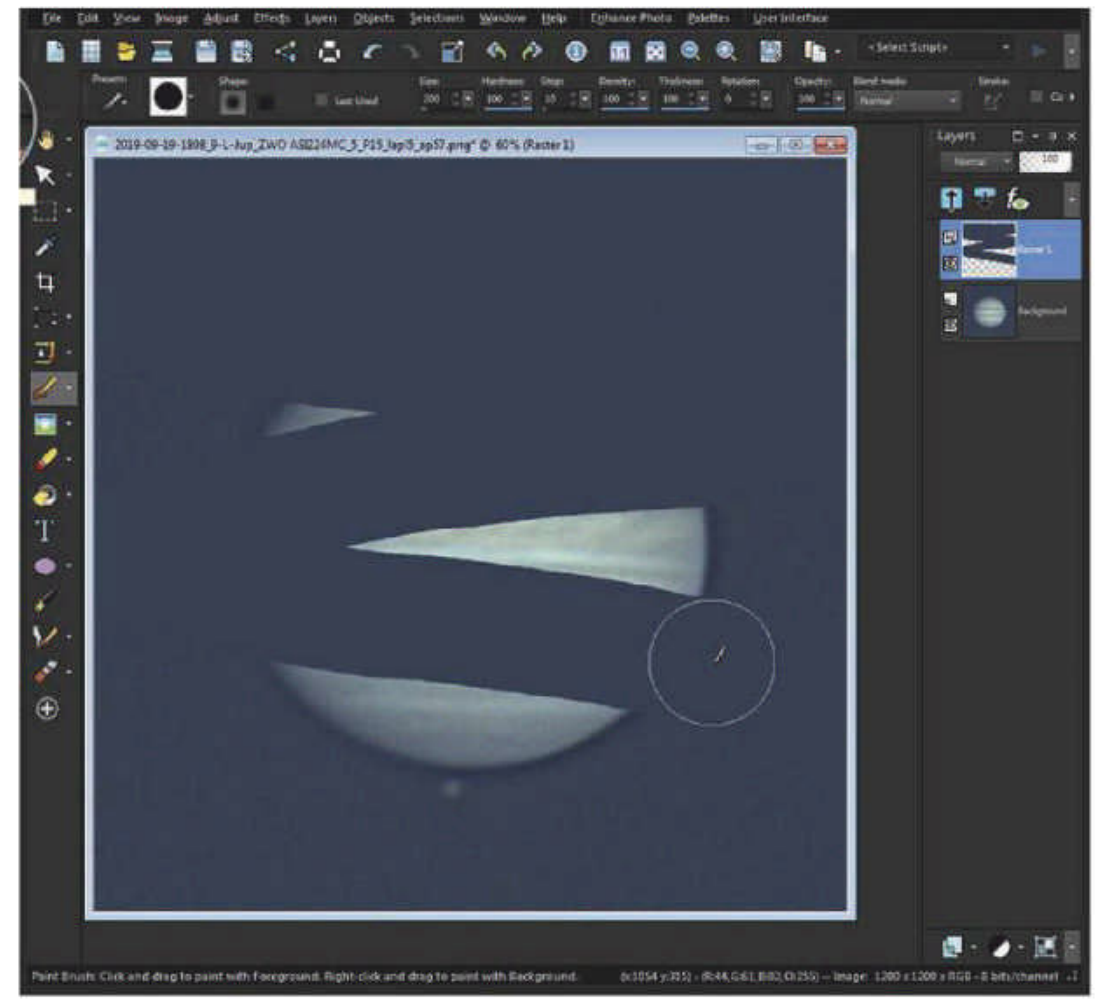
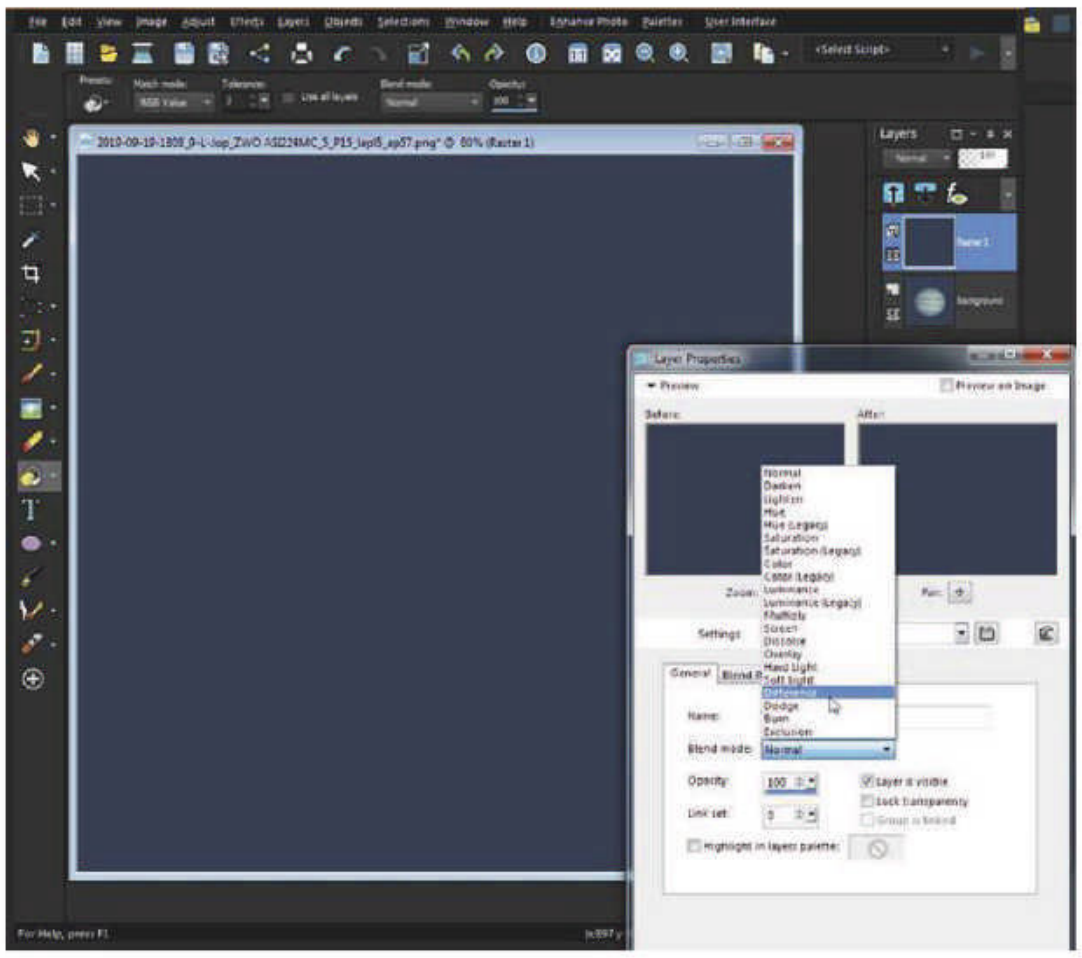


▲ Stage 1: use the Eyedropper tool to set the default program colour to the colour and brightness of the bluish twilight sky

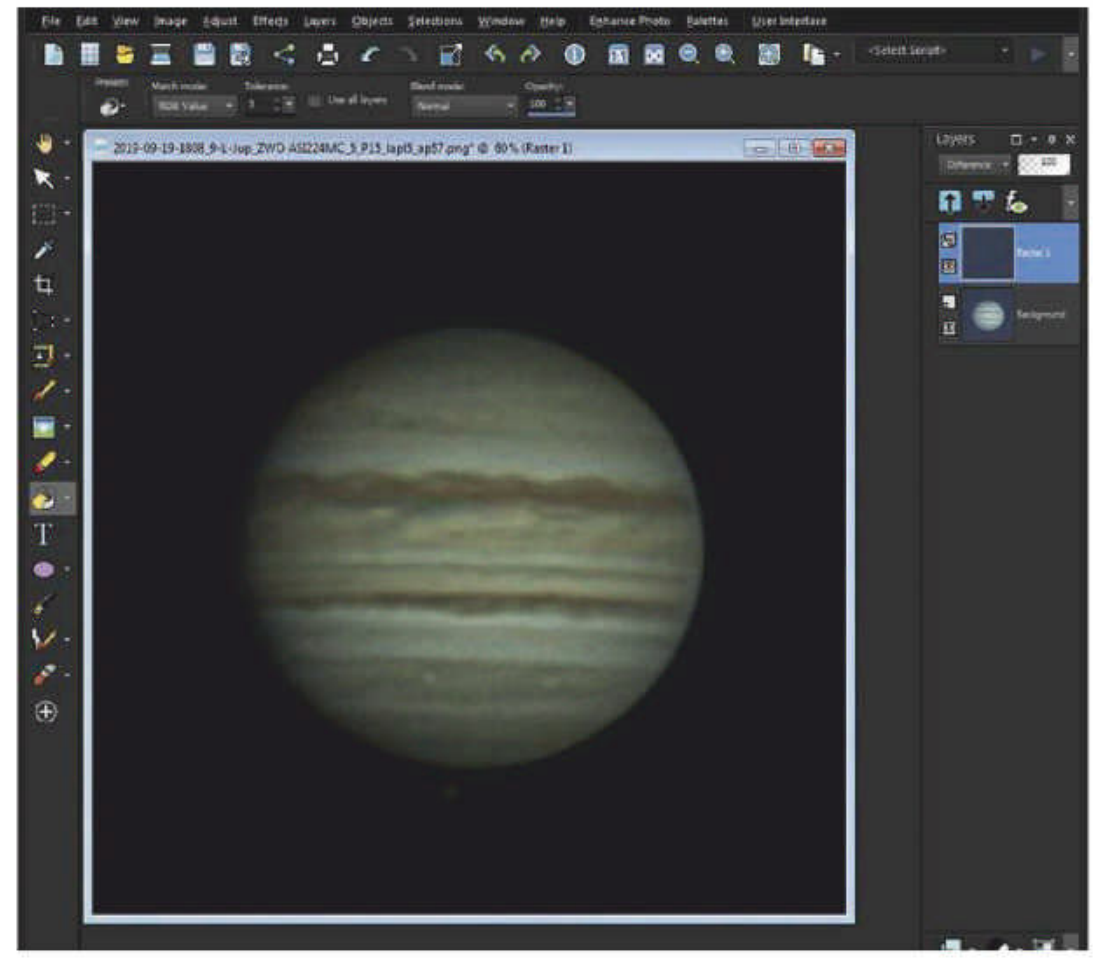


▲ Stage 2: use the Paintbrush to fill a new Raster Layer with the default colour selected with the Eyedropper tool

ALL PICTURES: MARTIN LEWIS



▲ **Stage 3: set the Blend Mode of the top blue-filled layer to Difference**



▲ **Stage 4: with the top layer set to Difference the bright wash of bluish twilight is subtracted, making the background sky black**

try and correct this using Red, Green and Blue sliders in RegiStax or Photoshop to give a more neutral balance, but this is difficult and can give odd results. A better solution is to remove the bluish wash from the whole of the frame. This will improve image contrast and reset the colour balance back to that which would be achieved in a dark sky. This is quite easy in an image-processing program such as Photoshop or PaintShop Pro and it provides the image-to-image consistency that is needed if you are going to combine separate images in WinJUPOS to improve signal-to-noise ratio.

Out of the blue

To apply the correction method, you should first process your videos as normal using a stacking program such as AutoStakkert! or RegiStax and then bring out the details using the wavelets tab in RegiStax. Avoid any histogram or gamma adjustments to the image. Once done, open the output image in your favourite image-processing program; here we are using PaintShop Pro.

Select the Eyedropper tool and set it to a largish selection area like 9x9 pixels. Use the dropper to sample the exact colour of the bluish background sky – clicking it on an area a bit away from the planet (see Stage 1, left). Doing this sets the program's default colour to match the sky background in hue and brightness. Next, go to Menu > Layer > New Raster Layer, to create a new layer on top of your twilight-affected planet image. This newly created top layer should now be filled with the colour that's just been selected. Select the layer and fill it all in with the selected foreground colour using the Paintbrush tool, or with the Flood Fill tool (see Stage 2, left). After this you will have your twilight-affected planet as the bottom layer hidden by the new top layer which you have filled with the same colour as the bright twilight sky.

Martin Lewis is a planetary imager. He was shortlisted at the IIAPY in 2019 for 'Black Saturn'

Now for the magic: in the Layer palette double-click on this colour-filled top layer and change the Blend Mode for that layer to Difference and click OK (see Stage 3, above). Suddenly the twilight wash is subtracted from the planet layer and you're left with an image without the contrast-robbing, colour-changing effects of the bright twilight sky. The image may be dim, but the colour will be reset to what you would get with a dark sky and the background should now be properly black (see Stage 4, above).

Finally, merge the two layers: Menu > Layers > Merge all. You can now finish your processing as normal to achieve the final image (see below).

Stage 5: the final Jupiter image after further brightness and colour balance correction

Your best photos submitted to the magazine this month

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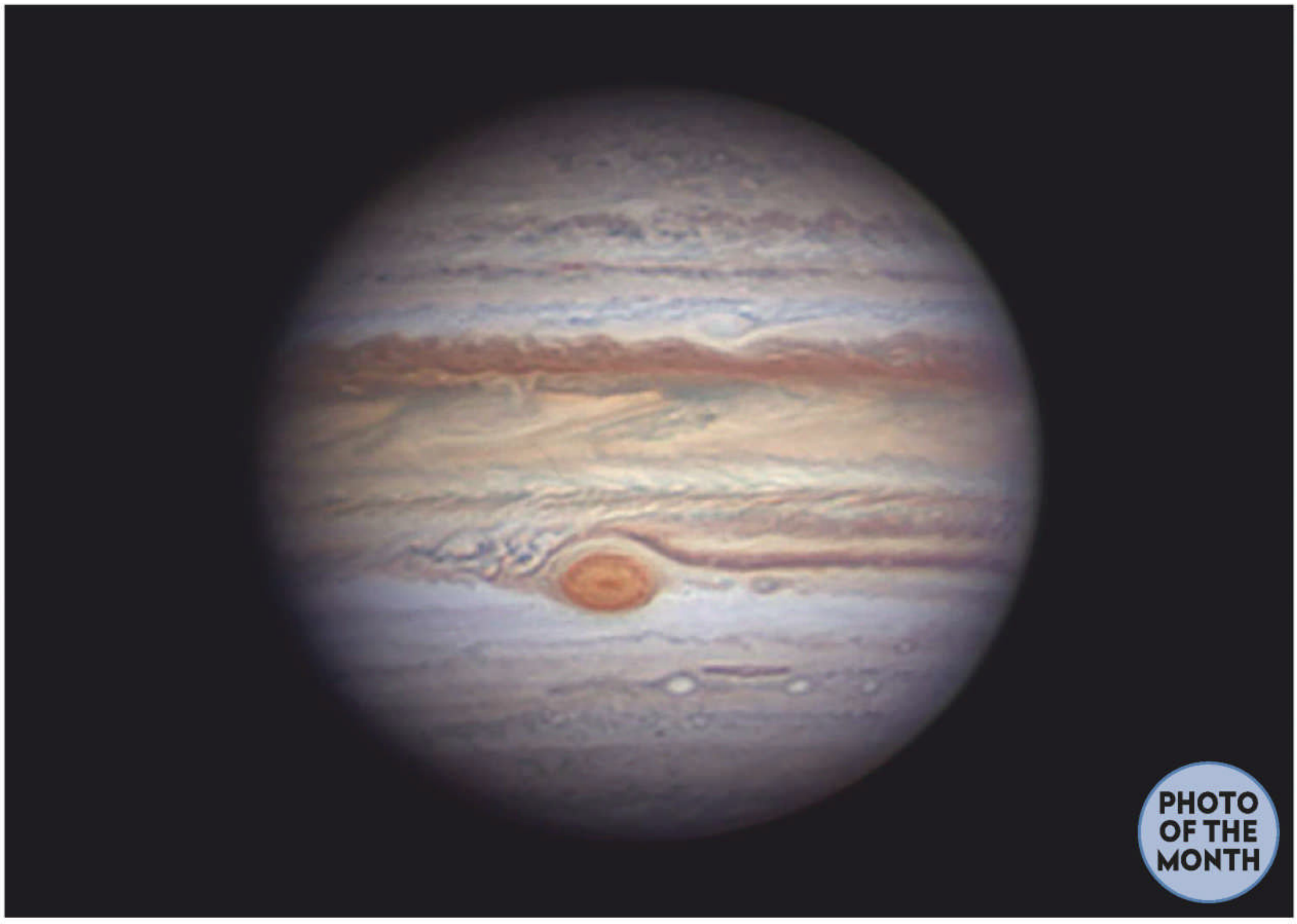


△ Jupiter

Rouzbeh Bidshahri, Dubai, 25 July 2019

Rouzbeh says: "Jupiter has always captivated astronomers with its ever-changing features. The main challenges for photographers are the constant instability of the image caused by atmospheric turbulence, the rapid rotation of the planet and the small apparent size from Earth. This image was captured on a night with calm atmospheric conditions, with advanced imaging and processing techniques. The final result yielded a relatively high-resolution image with details visible inside the Great Red Spot as well."

Equipment: ZWO ASI 290 mono camera, Celestron C14 Schmidt-Cassegrain telescope, Losmandy Titan mount
Exposure: 20,000 RGB video frames stacked
Software: FireCapture, AutoStakkert!, WinJUPOS, Astra Image

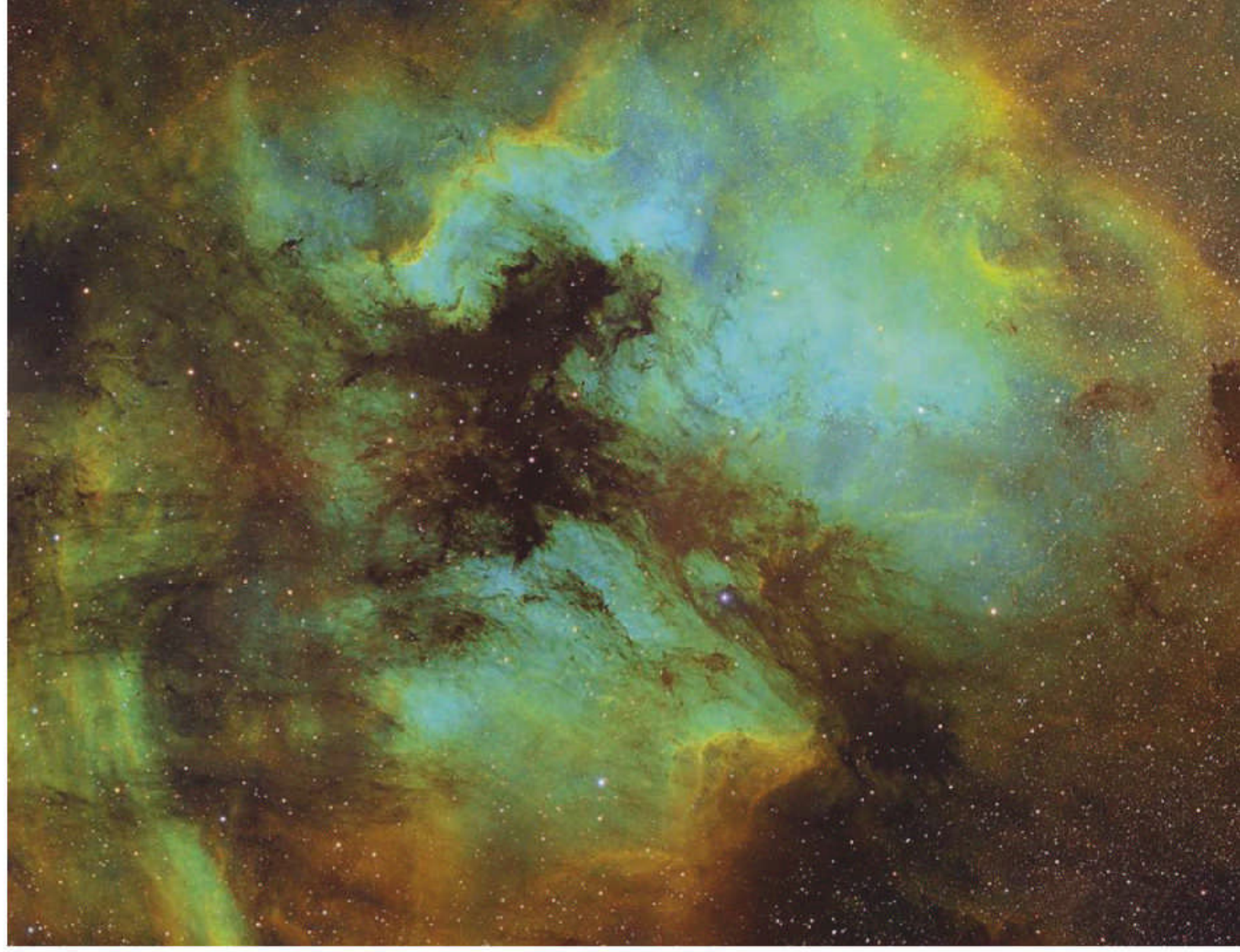
Rouzbeh's top tips: "Planets are typically captured with reflectors in the 8- to 14-inch range. Collimation, temperature acclimatisation and focus are critical. USB 3.0 'planetary' cameras are preferred. An ADC (analog to digital converter) is advised with colour cameras. Coupled with software like FireCapture, tens of thousands of frames can be captured to 'freeze' the atmospheric turbulence. Aim for f/- ratios of three to six times your camera pixel size. AutoStakkert! can identify and stack the best frames. Derotation using WinJUPOS increases the capture window from a few minutes to half an hour. And lastly, try to find the best seeing using forecasts, experience and patience!"

North America and Pelican Nebulae ▷

Jenny King, Kent, 25 August–8 September 2019

Jenny says: "I took this four-panel narrowband mosaic from my garden observatory. There are 10x 20-minute exposures on each channel, or 40 hours plus throwaway subs. I used Astro Pixel Processor (APP) to register and stack the exposures, but ended up using Photomerge in Photoshop to get them to stitch. I think it's my best image."

Equipment: QSI 690 CCD camera, TS Optics TSQ-71ED quadruplet flatfield refractor, Sky-Watcher EQ6 mount
Exposure: 4-panel mosaic, 40 hours, 10x20' per channel **Software:** SGPro, APP, Photoshop



◁ Milky Way

Athanasios Theodorou, Gavdos, Greece, 1 September 2019

Athanasios says: "The location was easy: Gavdos Island in Greece – Europe's southernmost point – almost devoid of light pollution. My recently acquired technical skills, along with the grandeur of the Milky Way soaring above, made the whole experience fascinating."

Equipment: Sony A6300, Sigma 16mm f/1.4 lens, tripod
Exposure: ISO 4000, 15" **Software:** Lightroom, Photoshop

△ Orion Nebula

Chris Grimmer, Norfolk, April 2019

Chris says: "The Orion Nebula is usually captured in full colour or as a hydrogen-enhanced colour image. I went for a narrowband image and captured this over three February nights in a multiple-night clear spell."

Equipment: Starlight Xpress H694 mono camera, William Optics GT81 apo refractor, MoonLite focuser, iOptron CEM60 mount **Exposure:** Ha 6 hours, OIII 3h
Software: SGPro, MaxIm DL, Photoshop

◁ Across the Moon

Paul Gavey, Guernsey, 5 September 2019

Paul says: "What I like about this photo is the plane is nicely placed on the first quarter Moon. I have been trying for quite a number of years to get a photo of a plane crossing the Moon at night with no success, so I was very pleased and extremely surprised to finally get this one as I feel it was a once in a lifetime chance. I'm pleased with the overall result considering no telescope was used and it was a hand-held shot."

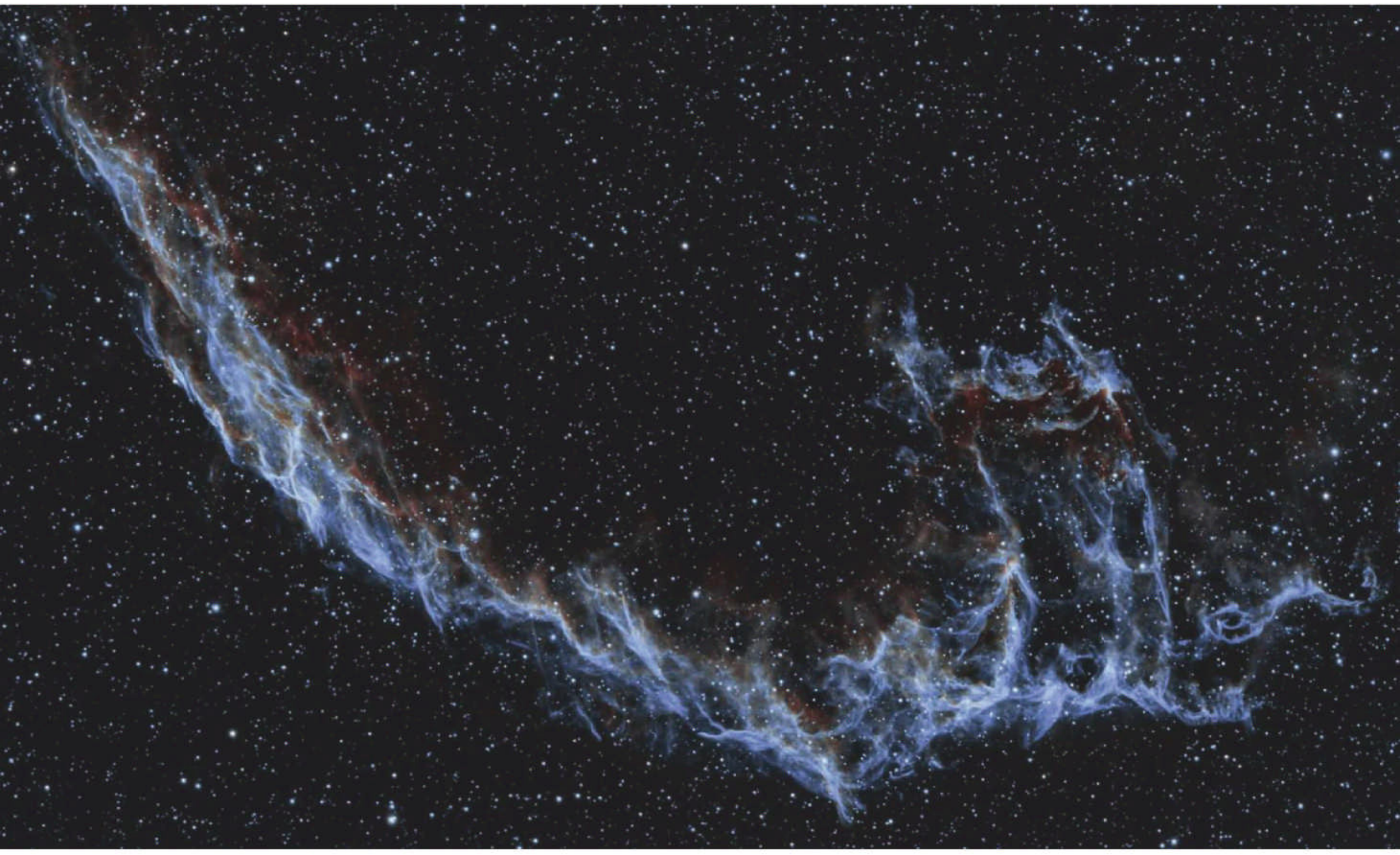
Equipment: Canon 5D MK II DSLR, 200–400mm lens
Exposure: ISO 2000, f/5.6, 1/2500"

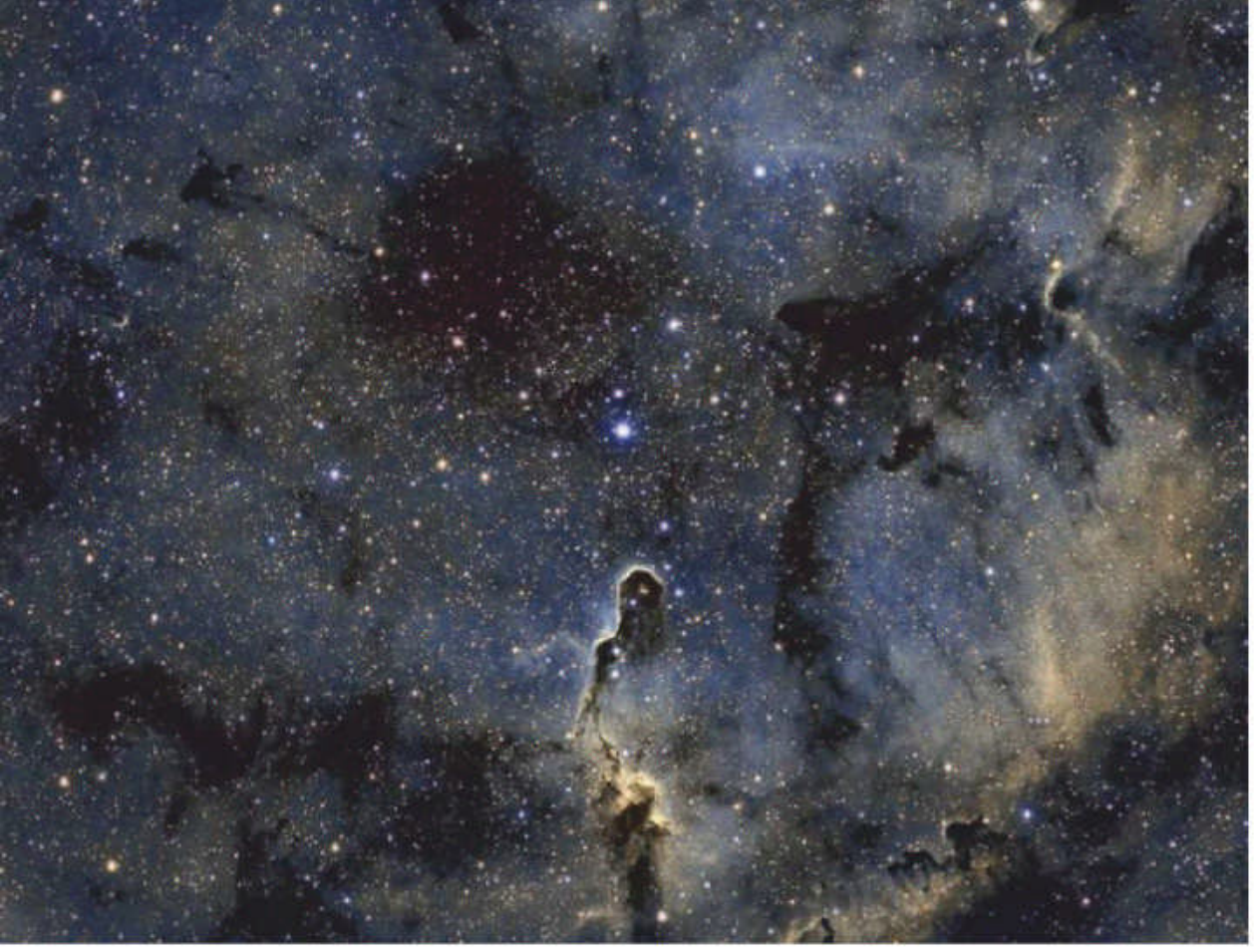
▽ Eastern Veil Nebula

Alec Alden, Colchester, July and August 2019

Alec says: "This was taken in my back garden in Colchester where there's plenty of light pollution from local houses and street lights. I was very happy with how well the narrowband filters kept this at bay."

Equipment: ZWO ASI 1600MM mono camera, Sky-Watcher Equinox 120ED refractor, Sky-Watcher EQ6 mount
Exposure: Ha 100x4', Ha OIII 100x4'
Software: SGPro, PixInsight





◁ Elephant's Trunk Nebula

Jack Sharp, Norfolk, April 2019

Jack says: "This image was my first proper attempt at imaging and processing with the Hubble palette and it's the first time I've captured a large dataset on one target (16 hours). I learned a lot while processing this one and I'm really pleased with the final result. It definitely helped having so much total integration time."

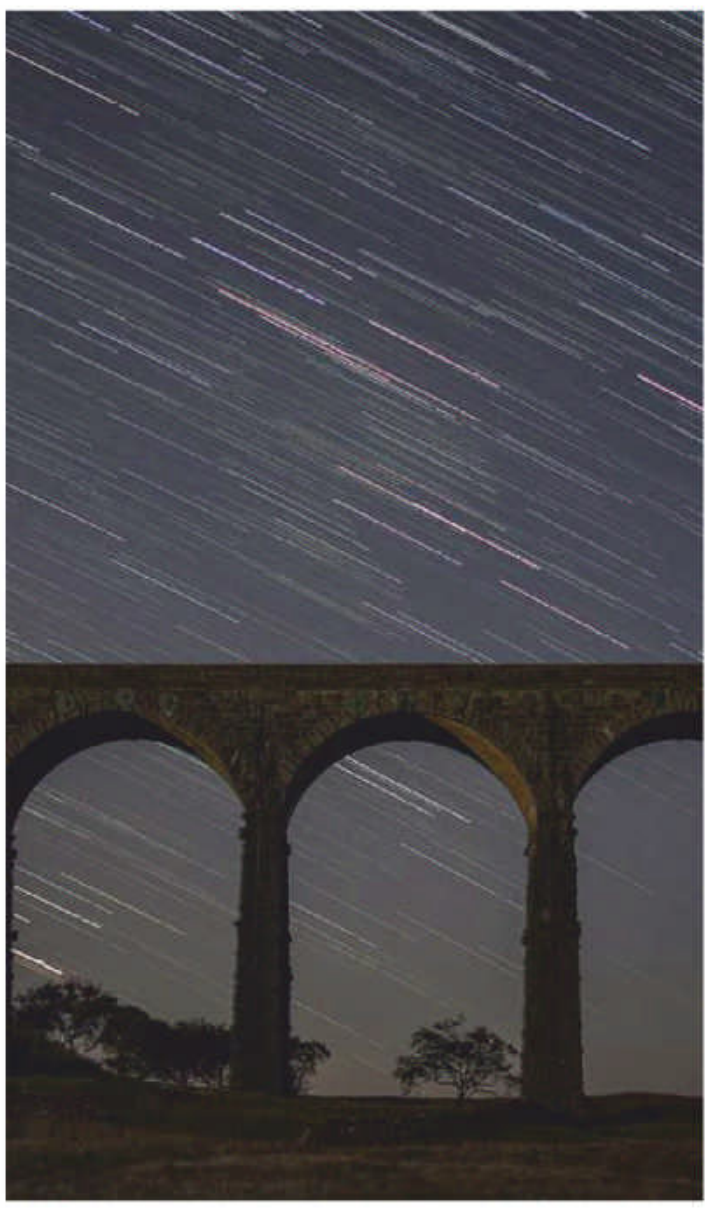
Equipment: ZWO ASI 1600MM-Pro mono camera, Altair Astro 70EDQ-R apo refractor, Sky-Watcher AZ-EQ6 GT mount **Exposure:** 5' and 10', Ha 5h, SII 5h, OIII 6h **Software:** APT, PixInsight

The Triangulum Galaxy ▷

Steve Heliczer, Frenegal de la Sierra, Spain, September 2019

Steve says: "I took this image on a recent astronomy holiday at e-EyE in Fregenal de la Sierra with three other members of Hertford Astronomy Group. This is my 'first light' image with my new camera, and shows what is easily possible with the new breed of ultra-high sensitive CMOS colour cameras."

Equipment: ZWO ASI 294 camera, Tecnosky 4-inch 100Q f/5.8 quadruplet apo refractor, AVX mount **Exposure:** 20x300" **Software:** SharpCap, DeepSkyStacker, Paintshop Pro



◁ Star Trails

Daniel McNamara, Yorkshire, 20 September 2019

Daniel says: "I chose the location at Ribblehead Viaduct for its dark skies. This shot is very different to my other star trails. I was amazed at how well it came out after stacking."

Equipment: Nikon D7200 DSLR, Nikkor 35mm f/1.8 lens, Manfrotto Befree Advanced tripod **Exposure:** ISO 1600, 56x767"

Software: Sequator

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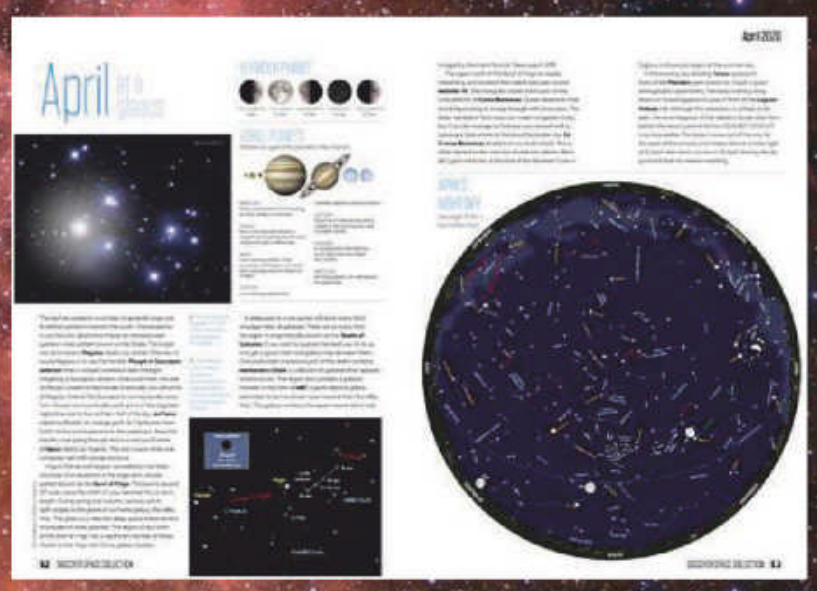

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REVIEWS

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86

How well does Bresser's Messier MCX-102 meet the needs of an astronomer who's just getting started?

PLUS: Books on Einstein in England, the memoirs of NASA's Kathryn D Sullivan, and a roundup of must-have gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★½ Very good
★★★½☆ Good ★★½☆☆ Average ★½☆☆☆ Poor/avoid

Bresser Messier MCX-102 Go-To EQ/AZ telescope

Begin your observing adventures with an effective multi-mode system

WORDS: PAUL MONEY

VITAL STATS

- Price £599.99
- Optics 102mm (4-inch) Maksutov -Cassegrain system
- Focal length 1,470mm, f/14.4
- Mount Fork-style EQ/AZ Go-To mount
- Hand controller Computerised, with 8-line LCD display and large database
- Tripod Adjustable tripod with accessories leg spreader
- Power 8xAA batteries or 12V external power supply
- Extras Red dot finder, 26mm (1.25") eyepiece, bubble level and compass, smartphone holder
- Weight 3.5kg
- Supplier Telescope House
- Tel 01342 837098
- www.telescope house.com

The Bresser Messier MCX-102 Go-To EQ/AZ telescope is a complete system allowing anyone who is just beginning their astronomical adventures to explore the night sky or even use it for terrestrial viewing. The system comprises a 102mm (4-inch) Maksutov-Cassegrain telescope with a Go-To computerised mount, tripod, red dot finder, 26mm eyepiece and smartphone holder. The tripod also has an in-built equatorial-adjustable wedge so it can be used in equatorial (EQ) or altazimuth (AZ) mode.

The 102mm front objective lens has a long focal length of 1,470mm that gives a focal ratio of f/14.4. The Maksutov-Cassegrain optical design folds the light path so that the long focal length fits into a shorter tube length of only 32.8cm, creating a compact system that is easily portable. The optical tube comes already assembled on the fork mount, so assembly onto the tripod is straightforward. However, if you are planning to use batteries to power the system, the battery compartment lies underneath the mount – taking 8xAA batteries – so these have to be installed before attaching to the tripod.

An object lesson

The computerised handset, or 'handbox' as Bresser calls it, does not list the total number of objects in its database, and neither do the specs online, but it does cover all the Messier, NGC and IC deep-sky catalogues, bright stars, the Solar System, including the Sun and Moon (but not comets or asteroids) and user-added objects. The rubber buttons are easy to operate, and the display has a generous eight-line readout, giving a lot of information depending on the mode you are in at the time. Once initialised with date, time and location it's important to ensure you are in the correct mode, altazimuth or equatorial, before proceeding to perform alignment. We found it relatively easy to set up for either mode and our first test run was in altazimuth. We aligned using the three-star routine and aimed at Altair, the brightest ▸

All for one

Versatility is the name of the game and the MCX 102 can be used in a variety of guises depending upon your needs providing for altazimuth, equatorial and table top modes all in one package. For basic views, either terrestrial or astronomical, the altazimuth mode can be used for terrestrial viewing and nature observation, and in powered mode it can still be aligned with up to three stars for Go To altazimuth performance. By using the built in polar wedge on the tripod, the system can also be set up as an equatorial mounted scope, which can track targets, following their motion across the sky and keeping the view in the same orientation.

Bresser has also designed the fork mount and scope to be used in a table top configuration, doing away with the tripod, for a quick set up and observe session that is ideal for a family around a table. With the base only requiring batteries there is no need for power packs or mains cables, simplifying the setup for a quick grab and go system.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Optics

The 102mm Maksutov-Cassegrain system has a focal length of 1,470mm, giving a focal ratio of f/14.4. The optics are multi-coated for better light transmission and gave good views of our targets with the supplied 26mm eyepiece, with only minor distortion towards the edge of the view.

SCALE

Fork style Go-To mount

The fork style mount comes preassembled with the optical tube in place and it can be freely moved about on both axes by loosening the clamps. It has a graduated scale on one of the forks for setting up the initial altazimuth configuration and underneath it has a compartment for the 8xAA batteries.

Hand controller

The computerised hand box has an eight-line display with a variable red-screen illumination and plenty of objects covering most of the popular targets in the sky, including the deep-sky and Solar System, although we did note there was no double-star listing. The handset was easy to use in the dark.

Tripod and accessories holders

The steel tubular-legged tripod is adjustable, allowing for a range of height for a more comfortable viewing position, while providing a good support for the MCX-102. The eyepiece spreader bar can hold three 1.25-inch fit eyepieces and the tripod top can be adjusted for altazimuth or equatorial mode.

FIRST LIGHT

KIT TO ADD

1. Bresser lithium power supply

2. Bresser PL 30mm eyepiece 1.25-inch

3. Bresser carry case and tripod softbag kit

► star in Aquila, for our field of view test. The star was sharp, across 80 per cent of the view, using the supplied 26mm eyepiece much to our satisfaction. We did have a niggle with the focusing knob as we found it had a little play, which seemed to move the view off to one side, but this may have been a one-off occurrence.

Visual prominence

We toured the late summer and early autumn sky, starting with the Ring Nebula, M57. Although the alignment didn't always put our target in the centre of view, we could fine tune and centre it every time. M57 was a nice oval smoke ring using the 26mm eyepiece, so we slewed to the Dumbbell Nebula, M27, and it was a lovely haze of light pinched in the middle. The Great Cluster in Hercules, M13, was a haze of stars nicely seen.

We turned to Albireo and were rewarded with a colourful rendition of the orange and gold primary star contrasting with the pale sky blue of the secondary. We wanted to increase the magnification but there is only one eyepiece supplied, which is a shame as a 2x Barlow would have enhanced the system. We used the supplied eyepiece for a nice view of the Wild Duck Cluster, M11, the Omega Nebula, M17, and the Andromeda Galaxy, M31, followed by the Pleiades, M45.

On another night in equatorial mode we toured many of the same objects, but also caught Jupiter and Saturn low down, giving views of former's belts and moons and the latter's rings. The Moon was enjoyable, with plenty of detail to be seen in the 26mm eyepiece. We imaged it with the supplied smartphone adaptor, using our iPhone 7+, but really this is a visual system for the most part. The flip mirror system at the back allows for a camera to be attached, but you have to take care as there is a limitation on how high you can aim before a camera catches the base.

We're pleased to announce that overall the Bresser Messier MCX-102 Go-To EQ/AZ scope does the job required, despite the slight focuser issue and the lack of a second eyepiece or Barlow lens.

VERDICT

Assembly	★★★★½
Build & Design	★★★½
Ease of use	★★★★★
Features	★★★½
Optics	★★★★★
OVERALL	★★★★★

WWW.THESECRETSTUDIO.NET X 2, PAUL MONEY X 2

▲ A cropped Moon image, taken with a smartphone adaptor and iPhone 7+, at 1/168th' with ISO 20 and f/1.8

▲ A cropped view of Albireo stacked with 355 frames, taken with a GPCAM 290C camera

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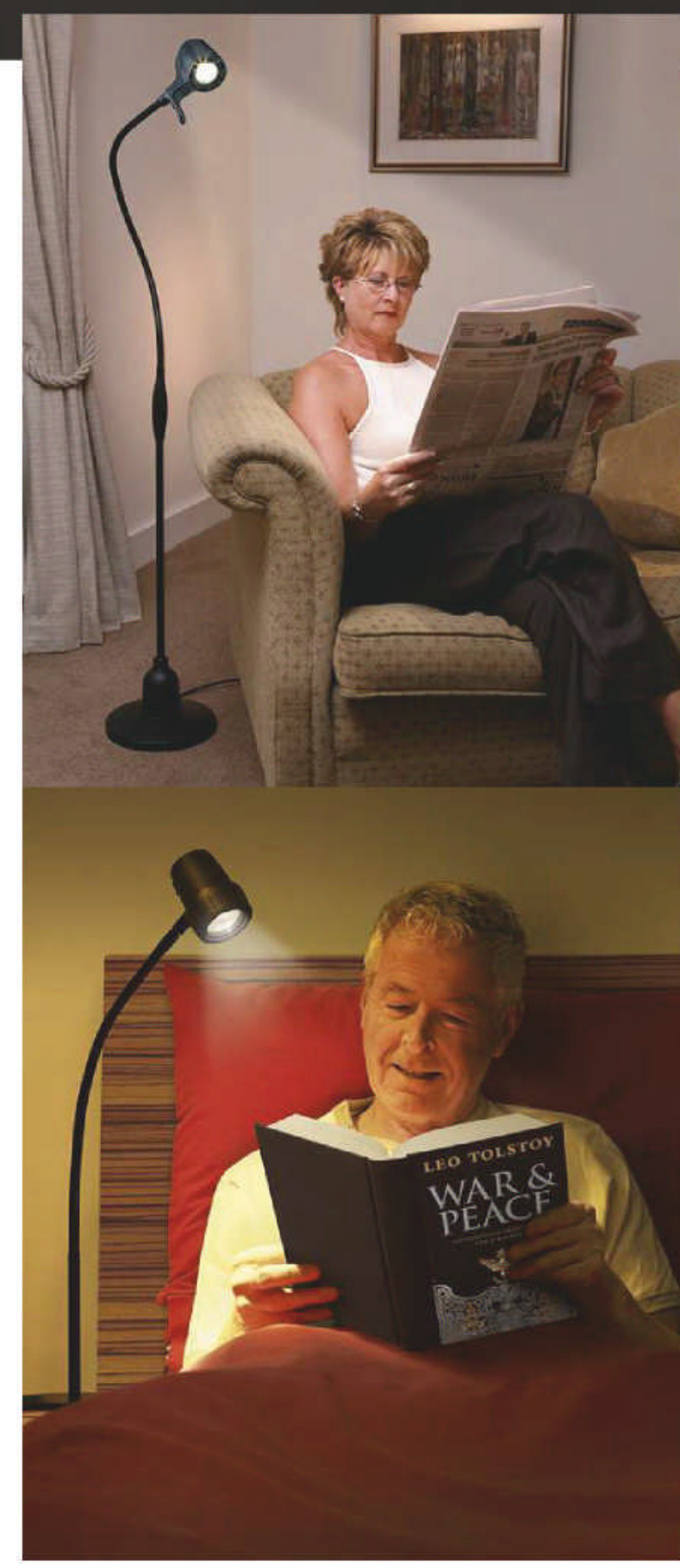

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FIRST LIGHT

Orion StarBlast 90mm altazimuth travel refractor telescope

An all-in-one beginner's scope with all the accessories you need to start observing

WORDS: STEVE RICHARDS

VITAL STATS

- **Price** £203.99
- **Optics** 90mm achromatic refractor
- **Focal length** 500mm (f/5.6)
- **Mount** Altazimuth pan and tilt
- **Extras** 45° correct-image 5x20 finderscope, 25mm and 9mm Kellner eyepieces, 2x Barlow lens, 1.25-inch 45° correct-image star diagonal, red LED torch, Moon map, carry bag, manual and planisphere
- **Weight** 4kg
- **Supplier** Orion Telescopes & Binoculars
- **Tel** 0800 0418146
- **https://** uk.telescope.com/

ALL PICTURES: WWW.THESECRETSTUDIO.NET

For many of us, it's so easy to forget what a first telescope was like. For some of us, it was a cardboard tube with a 1.5-inch lens that blew off when the smaller diameter cardboard tube focuser was pushed inwards – how things have changed. The Orion StarBlast 90mm altazimuth travel refractor kit would have been the stuff of dreams back then, yet here it is. It's a complete beginner's telescope, comprising a 90mm achromatic refractor mounted on an altazimuth mount, supplied with all the extras that a budding astronomer needs to get started.

The scope is nicely finished in a white gloss on alloy tube with black plastic fittings. The stylishly sculpted dew shield has a captive rubber dust cap so you won't lose it at the end of an observing session at a dark-sky location. Thoughtfully, there is a fluid-filled compass mounted on the top of the telescope to aid in finding objects when using the supplied planisphere.

A 90mm aperture telescope with a focal ratio of f/5.6 should yield good observations of many objects from the Moon and planets to a wide range of deep-sky objects, so we were keen to discover how it performed on the night sky and whether it would help or hinder the kindling of an interest in astronomy.

Back to basics

The primary lens comprises an achromatic doublet with an anti-reflection coating to improve light transmission. During daytime terrestrial observing, we noted a small amount of chromatic aberration on hard transition edges, but no more than we would have expected with this design of lens.

Kellner eyepieces, like those supplied, are a three-element design and best-suited to longer focal length scopes. To get you started, however, they are more than adequate, but as you gain experience you will want to replace them with something better. The eyepieces didn't have filter threads in their barrels.

The first task was to align the correct-image finderscope with the telescope using a daytime object over a quarter of a mile away, but we were unable to do so with the protective rubber collar in the finderscope's mounting ring in place. However, with the collar removed, adjustment was successful using the three adjustment thumbscrews.

Moving on to night-time observations, a lovely quarter Moon showed plenty of detail in the craters ▸

Off to a good start

Beginners to astronomy require more than just a scope to get them started and a sensibly bundled observing outfit like the Orion StarBlast 90mm altazimuth travel refractor telescope kit provides everything needed to take those first forays into celestial observations.

As well as the scope, altazimuth mount and three section extending tubular legged tripod, there are 25mm and 9mm Kellner eyepieces, a 2x Barlow lens, a detailed Moon map, a correct image 5x20 finderscope, a 45° correct image diagonal, two planispheres covering 30° to 50° and 40° to 60° latitude and a red light LED torch. All the component parts are neatly stored in a rugged nylon shoulder bag to keep everything in one place and make it easy to transport. The eyepieces are supplied in protective plastic cases that are retained securely in a nylon pouch with the finderscope and Barlow.

Assembly is quick and straightforward with an excellent printed manual to guide the first time user through the process of setting up and locating their first celestial objects.

SCALE

Correct-image finder

The correct-image finderscope has a magnification of 5x and, like the scope itself, it's suitable for both terrestrial and celestial use. Its 45° angle makes it comfortable to use for terrestrial object location, but less so for observing the night sky.

Tripod

The tripod has 1.25-inch diameter stainless steel legs with plastic hinges, making it lightweight to carry, but stable, especially in its retracted state with the plastic leg spreader installed. The height to the centre of the telescope tube is generously adjustable from 79cm to 146cm using two extension legs.

Eyepieces

The scope is supplied with both 25mm and 9mm Kellner eyepieces, providing magnifications of 20x and 56x respectively. The 25mm version gave excellent views and worked well with the supplied Barlow lens, but the 9mm version was not as good. We could observe the full field of view when wearing spectacles.

FIRST LIGHT

KIT TO ADD

1. Sirius Plössl eyepieces set: 10mm, 17mm and 25mm

2. Moon filter

3. Orion SteadyPix Quick smartphone telescope photo adaptor

▸ along the terminator using the 25mm eyepiece with some chromatic aberration visible on the lunar limb. However, the 9mm eyepiece didn't improve our observations and we found that when we wanted to look closer at any celestial object, we got better results using the Barlow lens to amplify the view through the 25mm eyepiece. Jupiter was small through this telescope, but we could easily see its four largest moons as pinpricks of light, different from the appearance of stars. We were just able to distinguish Saturn's rings but not sufficiently for that 'wow' experience that beginners should enjoy on first observing this object. That said, the planet only reached an altitude of just under 17° during the review period so observing conditions were poor.

Target practice

We carried out a star test using the bright target Vega and noted that star shapes were good – out to about 75 per cent of the field of view – but astigmatism caused some blurring. We observed a range of brighter deep-sky objects from the Messier catalogue, including the Andromeda Galaxy, M31, the Pleiades, M45 and globular clusters M15 and M92. These were most enjoyable, but they did show up two niggling design issues. In common with other scopes of this design, the 45° correct-image diagonal, while fine for terrestrial observing, became uncomfortable for observing objects high in the sky unless we were seated low to the ground. For astronomical use we would have preferred a conventional 90° star diagonal. Also related to observing objects higher in the sky, the pan and tilt handle caught on the shoulders of the tripod head, so we had to keep rotating the tripod to observe some objects.

For a beginner, this outfit would make an attractive and comprehensive starting package, especially if it was intended for terrestrial observing as well.

VERDICT

Assembly	★★★★½
Build & design	★★★☆☆
Ease of use	★★★½☆
Features	★★★★☆
Optics	★★★½☆
OVERALL	★★★½☆

Rack and pinion focuser

The single-speed, straight-cut rack and pinion focuser had a pleasant feel with only a minimal amount of 'nodding' when changing the direction of focus. A nice touch was the inclusion of an internal plastic collar that protects the eyepiece barrel from damage when tightening the 1.25-inch eyepiece holder's thumb screw.

Achromatic doublet lens and dew shield

The coated f/5.6 achromatic doublet lens comprises two different glass types that work together to minimise chromatic aberrations, which are an unwanted effect that causes coloured halos around bright objects. To help increase contrast, the fixed dew shield excludes stray light, as well as keeping dew at bay very effectively.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

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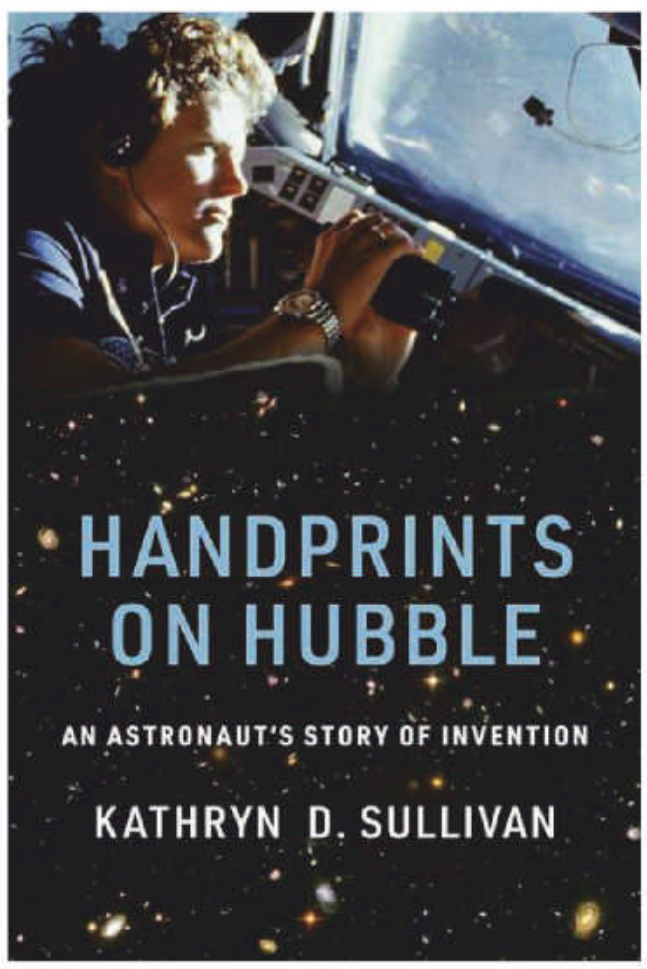


Handprints on Hubble

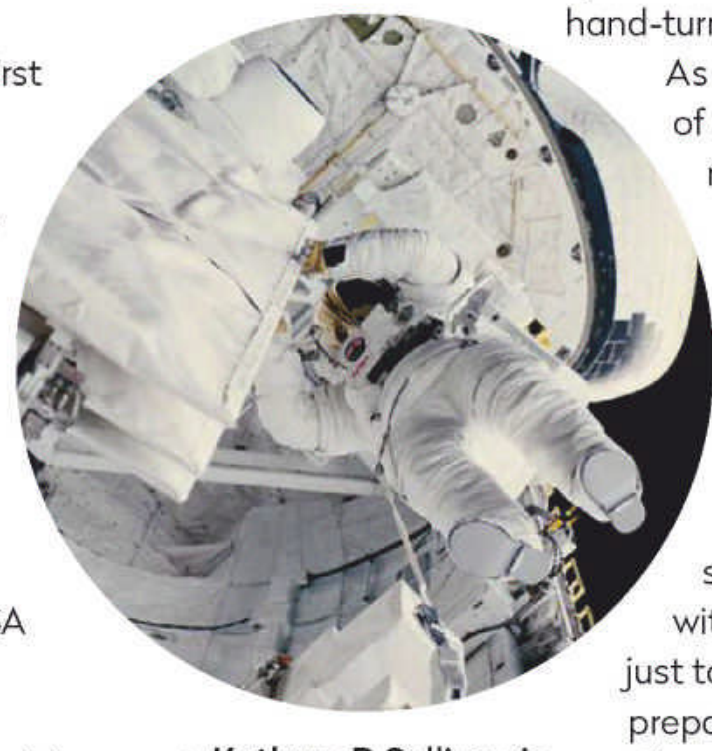
Kathryn D Sullivan
The MIT Press
£22 ● HB

Penned by America's first female spacewalker, *Handprints on Hubble* tells the story of Kathy Sullivan, whose career took her from a pressurised space suit to the highest altitude ever reached by the Space Shuttle. As one of the first women picked by NASA for astronaut training, her memoir mixes autobiography with a solid appreciation of the Hubble Space Telescope, arguably the most important science instrument ever placed into orbit.

And Hubble is as much a character in this story as Sullivan herself. Both were 'born' in the postwar years: she as the daughter of a New Jersey aerospace engineer, the space telescope as an idea in the brilliant mind of physicist Lyman Spitzer. As Sullivan began astronaut training in 1978, so Hubble gained Congressional approval to move from concept into hardware.

Sullivan's determined inner strength arose from her mother's battle with depression and alcoholism, although a childhood fondness for adventure, maps and languages drove her towards an oceanography career and later – at the urging of her brother – into NASA. She established her credentials in a male-dominated world and devised spacewalking techniques with astronaut Bruce McCandless. They worked on Hubble and, in 1990, flew together to launch it.

Yet Sullivan sees herself as part of a far bigger picture. She paints portraits of McCandless – brilliant engineer, photographic memory, occasional tantrums – and Hubble's unsung heroes. We meet engineers who hand-sketched plans for the first 'maintainable' space telescope, figured out in their heads how to lay 41,800km of wiring and chose bolts and fasteners tough enough to withstand a rocket launch, yet sufficiently delicate to be undone by a hand-turned wrench.



▲ **Kathryn D Sullivan in the open cargo bay of Space Shuttle Challenger in 1984**

NASA

As a ringside spectator of Challenger, Sullivan's memories are tinged by tragedy and she remained soberly aware that she might never return from a mission. But she shares moments of levity, including synchronising watches with astronaut Sally Ride, just to 'look busy' as they prepared to board the Shuttle. And behind every scene Hubble itself looms large – "like a beautiful silver gift from Tiffany's" – whose contribution to understanding our place in the cosmos needs no qualification. ★★★★★

***Ben Evans** is the author of several books on human spaceflight and is a science and astronomy writer*

Interview with the author
Kathryn D Sullivan

What does it feel like to spacewalk?

Imagine being able to 'swim' anywhere in a room with just the touch of a finger, with no sense of falling, being right side up or upside down. The freedom of movement is magical, even when wearing a spacesuit that weighs 136kg on Earth. Although it weighs nothing in orbit, it still has considerable mass, which you learn to account for as you move.

Were there any scary moments during Hubble's deployment?

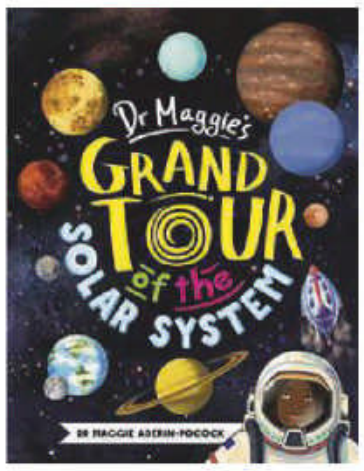
In orbit, the telescope began to sway left to right as soon as Steve Hawley began to lift it. This was a huge worry, because it filled the cargo bay with mere inches to spare. Any bump could damage its equipment. We all breathed a sigh of relief when it cleared the cargo bay walls. Another anxious moment was when the second solar array jammed. Bruce McCandless and I rushed to don our spacesuits and go outside to crank it out by hand. Luckily, it was an instrumentation problem they were able to fix with a software command. It was unlucky for Bruce and me, however: we were stuck in a partially depressurised airlock, between the Shuttle's cabin and outer space. Instead of doing a spacewalk and witnessing Hubble's deployment, we could only listen as events unfolded.

What is Hubble's legacy?

It transformed astronomy scientifically and socially, changing our understanding of how the Universe works and our place in it.

***Kathryn D Sullivan** was a crew member on three Space Shuttle missions. She is the Charles A Lindbergh Chair of Aerospace History at the Smithsonian Institute*

Dr Maggie's Grand Tour of the Solar System



Maggie Aderin-Pocock
Buster Books
£12.99 ● HB

If you fancy snowboarding off Pluto's slopes and frozen mountains, experiencing 'diamond' rain on Uranus or taking a 20-year plane journey from the Moon to the Sun, you could take a family trip around the Solar System with space scientist and presenter Dr Maggie Aderin-Pocock.

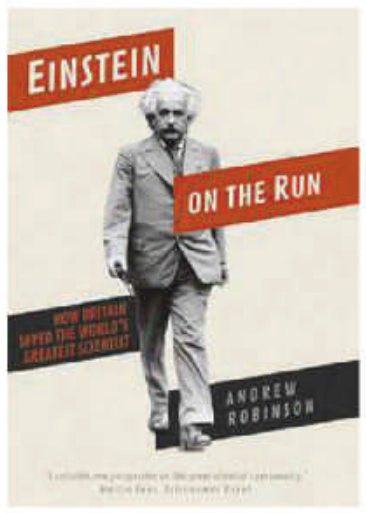
In her new book, aimed at older pre-teen children, a cartoonified Dr Maggie takes readers on an informative journey. It's beautifully designed, with an appealing layout and plenty of illustrations. The trip also includes delightful 'tour highlights' such as a stop at the largest volcano in the Solar System, Olympus Mons on Mars, three times the height of Mount Everest. Packing in the entirety of the Solar System, its planets, objects, exploratory missions and history in 120 pages aimed at children is no easy task. Aderin-Pocock has made a valiant effort to do so. The result is a thorough, accurate and informative book.

However, I couldn't help feeling that perhaps less might be more. There's about 16 pages of mission preamable before we set off, and the book is crammed with facts and figures in a way that clearly has educational value. But while it will appeal to kids already into space, I wonder if it will have enough draw to entice kids who are not space buffs.

I shoved the book under the noses of my children (aged 8 and 12). The reaction was somewhat 'meh', although that could just reflect their changing reading habits. Still, I do know my eight-year-old self would have loved this book, especially the stunning pictures and the Ship's Database at the end with its bite-sized stats. ★★★½☆

***Shaoni Bhattacharya** is a science writer and journalist*

Einstein on the Run



Andrew Robinson
Yale University Press
£16.99 ● HB

For all that is written about Albert Einstein, little before has focused on a curious episode in 1933 when he lived, in secret, in rural England. How he ended up there, why it needed to be secret and his reasons for leaving Berlin are all the subject of this new biography, *Einstein on the Run*.

This is certainly an engaging book, written by a seasoned biographer, Andrew Robinson, and filled with interesting insights backed up with pictures, poems and quotes from the main protagonists.

It tells the fascinating story of Einstein's life, science, growing fame and his relation to Britain running up to his brief stay in hiding here in 1933. It covers his development of relativity theory and its reception, his subsequent international fame, and the significance of his Jewish heritage both to how he was treated in Germany and elsewhere.

The story of why Einstein was in hiding is particularly intriguing, shedding light not only on 20th-century physics, but also on the politics of the time and how people responded to a growing, but not yet universally condemned, rise of fascism. In that sense, it feels a curiously timely book, looking at what it meant to be politically outspoken in a time of political uncertainty.

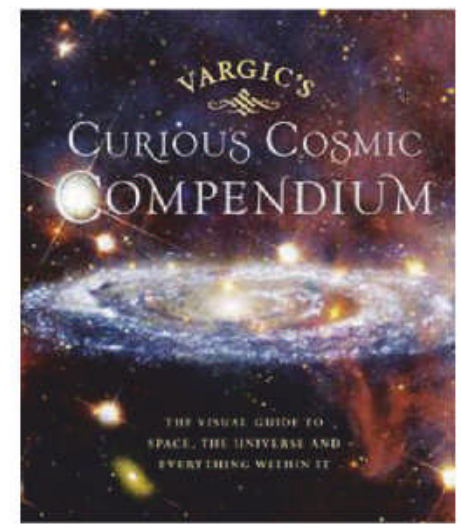
Some readers might be disappointed, given the promise of the title, that Einstein's time in Britain actually features fairly late in the book. For me, the depth given to the political and scientific context leading up to his stay in the UK, more than made up for this. ★★★★★

***Emily Winterburn** is the author of The Stargazer's Guide: How to Read our Night Sky*

GRIPPING READ

Curious Cosmic Compendium

Martin Vargic
Michael Joseph
£25 ● HB



Which is the biggest and the most massive star in the Universe? Where is it located and when was it born? All the answers to these questions as well many more, plus maps of places of universal importance, can be found in this well-illustrated book, *Curious Cosmic Compendium*.

The author, artist and Internet sensation Martin Vargic, displays the history and wonders of the Universe in the typically creative way that brought his *Miscellany of Curious Maps* and *Map of the Internet* such praise. In more than one hundred pages filled with facts and illustrations he takes the reader on a journey through the history of the cosmos. A collection of ancient drawings illustrates how humanity first became aware of the wonders of the night sky, while maps of planets and pictures of asteroids give an insight into the geology of our galactic neighbourhood and numerous charts reveal space as it was when the first atoms were formed. Also of interest is a periodic table in which the elements are arranged by their origin and place in the history of our Universe.

Some readers may find so many illustrations inordinate, but after all, Vargic is attempting to compile all kinds of processes that have happened over a period of 13 billion years. A personal highlight is a collection of images in which the Sun is replaced by other stars, so we see what 'sunsets' look like elsewhere in the Universe. This creates the feeling that we are part of an endless cosmic journey.

Alongside its sheer exhaustiveness, part of the book's appeal is that it reveals places that were undiscovered until recently, in a way that makes the reader believe we've been there already. ★★★★★

***Sandra Kropa** is a science journalist and writer*

Elizabeth Pearson rounds up the latest astronomical accessories

GEAR

1 Stellarium Mobile Pro

Price £7.49 (Android), £9.99 (iOS)
Supplier Stellarium Labs • **www.stellarium-labs.com**

With a huge catalogue of night sky objects, this planetarium app will help you navigate your way around the night sky. Developed by the original creator of Stellarium for desktop, the Pro version of the app comes with an increased catalogue and telescope control functionality.

2 Rigel SkyLite red and white torch

Price £28 • **Supplier** 365 Astronomy
Tel 020 3384 5187 • **www.365astronomy.com**

Control your torch's brightness without ever having to take your gloves off, thanks to the thumb wheel on this red and white flashlight. On the dimmest setting, a single 9V battery can last up to 320 hours.

3 Rohan Nordic jeans

Price £100 • **Supplier** Rohan
Tel 0800 840 1412 • **www.rohan.co.uk**

Enjoy your stargazing at any hour with these jeans. Special ceramic pigments in the fabric soak up the Sun's infrared radiation, helping you stay warm in the day, while the hollow-core yarn helps trap heat to keep you warm at night. Available in men and women's fit.

4 Space tape

Price £10 • **Supplier** Suck UK • **www.suck.uk.com**

Give anything you want a space theme with the help of these colourful masking tapes. The set comes with four different designs featuring the planets, the Moon, astronauts and a starry sky.

5 Explore Scientific 4.5mm 82º eyepiece

Price £133 • **Supplier** Telescope House
Tel 01342 837098 • **www.telescopehouse.com**

This eyepiece is specially designed to have a long eye relief and a wide field of view for a more comfortable, immersive viewing experience. The high-quality production, glass and coatings help to ensure clear views for years to come.

6 Orion U-mount

Price £517.99 • **Supplier** Orion
Tel 0800 041 8146 • **https://uk.telescope.com**

Do away with bulky counterweights with this altazimuth U-mount, which is specially designed to keep the centre of gravity balanced. Capable of supporting up to 11kg and measuring 28cm wide, this is a great mount for large binoculars or small telescopes.

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Shaoni Bhattacharya interviews Professor Willy Benz

Q&A WITH AN EXOPLANETARY SCIENTIST

While ESA's CHEOPS mission, due to launch by the end of 2019, won't find life, it will take the first steps towards characterising faraway planets

What is the CHEOPS mission?
CHEOPS (CHaracterising ExOPlanet Satellite) is the first small science mission from the European Space Agency (ESA) and its goal is to address some outstanding issues in exoplanet science. The mission aims to do ultra-precise photometry of stars already known to hold planets, to measure the size of the planets.

How will CHEOPS measure planets?
With photometry we look at a star and monitor the light we receive over time. If a planet passes in front, this will dim the light slightly, and that dimming is proportional to the planet's size. The bigger the planet, the more the light will be dimmed. This is a technique that has been used by other satellites such as Kepler from NASA, now TESS, and ESA will launch PLATO (PLAnetary Transits and Oscillations of stars) in a few years.

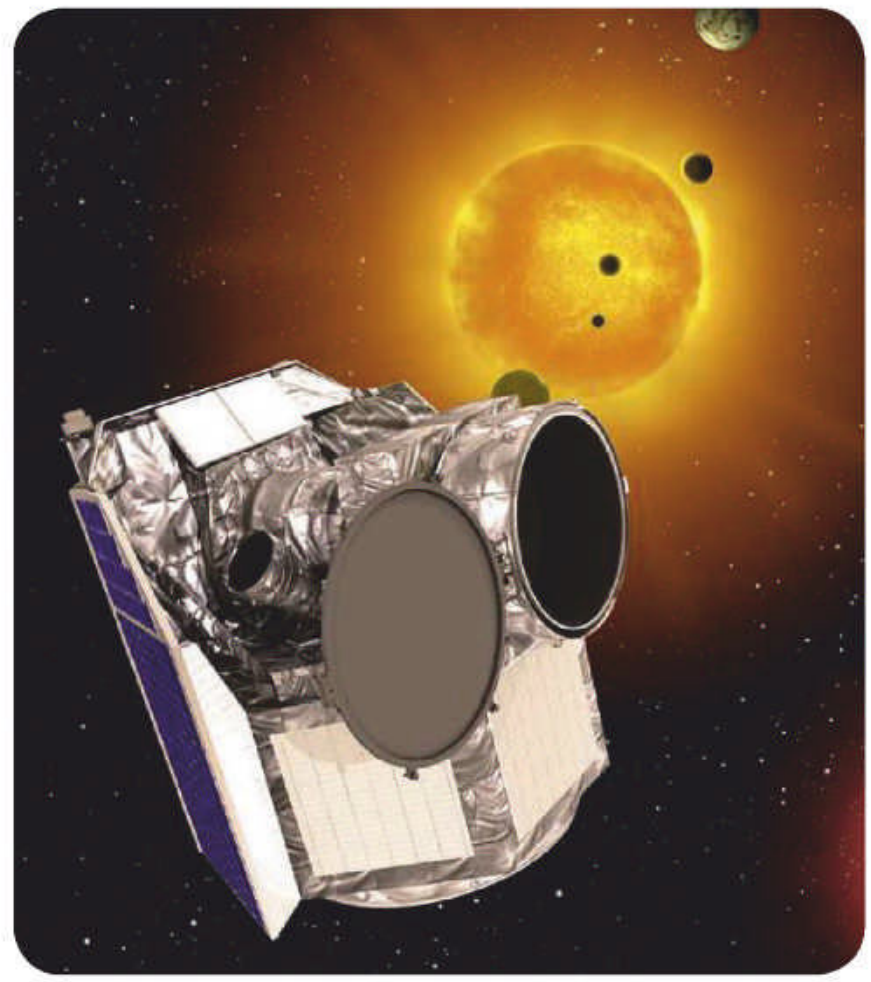
What makes CHEOPS very different from other missions so far applying this technique is that we are not looking for new planets. We are a follow-up mission: we look at bright stars which we know have a planet. We are trying to measure this dimming of the light more precisely and get a better measure of the planet's radius.

How can CHEOPS help our understanding of exoplanets?
We want to know more about exoplanets than simply that they exist: 25 years ago this was pure speculation – we knew only the eight planets of our Solar System. Now we know that planets may outnumber stars in the Universe. We want to know more. How big they are? What they are made of? How hot they are? Do they have an atmosphere?

But you have to do a number of measurements. If you have the planet's size and its mass, you can start computing its density, then you know whether its rocky or gaseous. You can start understanding its physical nature.

What have been the main challenges of the mission so far?
We must be able to measure the intensity of light to a high precision. This has been a challenge because the satellite orbits in low Earth orbit where there are lots of sources of stray light that may affect the precision.

We developed something that should measure light to 20 parts per million (ppm). When we tried to check this in the lab we realised that there is no light source on Earth sufficiently precise or stable that we could measure. We actually developed a super-stable light source to check whether our precision is good enough. You can't buy this off the shelf anywhere.



ESA/C. CARREAU

▲ **On target: CHEOPS will provide valuable data about the size of exoplanets**

What is the plan for the mission?
CHEOPS will be launching in mid-December. Its nominal lifetime is three and a half years – but secretly we hope for five.

Over the past four years we have prepared a science programme and built a list of a few hundred targets. But CHEOPS is also an open observatory – 20 per cent of its time will be "open time" to anyone in the community. Anyone with a good idea can submit a proposal to ESA.

How are you feeling about the launch of CHEOPS?
Now CHEOPS is waiting to be shipped to Kourou [in French Guiana] for launch, I'm getting nervous. The first thing I would like to see is a successful launch – that it gets delivered into the right orbit.

The next big tension then will be when the first images come down. Come the end of February or mid-March we will either be reassured that we have a system that works, or we might be scrambling to find a software fix for some problem. If, as we hope, everything goes well, then we will start getting the first science data in early April.

How might CHEOPS help find life?
CHEOPS is not going to find life. CHEOPS is an important element to measure exoplanets, and maybe some of the planets we will target later on for bigger facilities – like NASA's James Webb Space Telescope, or the ground-based Extremely Large Telescopes – to look at. CHEOPS is one element of a discovery chain to look for exoplanets, their properties and characteristics, and eventually down the line – for life.

Professor Willy Benz is the principal investigator of CHEOPS and professor of astrophysics at the University of Berne, Switzerland.

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch a glimpse of the Magellanic Clouds while Venus dominates the evening sky

When to use this chart

1 Dec at 24:00 AEDT (13:00 UT)
15 Dec at 23:00 AEDT (12:00 UT)
30 Dec at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

DECEMBER HIGHLIGHTS

High in the southern evening sky are the Magellanic Clouds. Looking like detached sections of the Milky Way, they are neighbouring galaxies and fellow members of the 'Local Group'. The Large Magellanic Cloud follows the Small Magellanic Cloud across the sky. They have something to offer observers using any instrument. While the naked eye shows the LMC's central 'bar', binoculars reveal the large nebulae, and scopes show numerous open and globular star clusters.

STARS AND CONSTELLATIONS

Culminating low in the evening sky is the constellation of Perseus, the Greek mythical hero. The variable star Beta (β) Persei was the first ever eclipsing binary found, its drop in brightness caused by a fainter companion passing in front of the primary every 2.87 days. It's also known as Algol, derived from the Arabic for 'head of the ghoul', or the Medusa slain by Perseus. He used its head to rescue Andromeda by turning Cetus, the Sea Monster, to stone. Both are located in nearby constellations.

THE PLANETS

After Venus and Jupiter's November close proximity, the planets separate with Jupiter lost by midmonth. Venus keeps its dominance of the early western evening sky, drawing nearer Saturn and overtaking on the 11th. Saturn follows Jupiter towards the Sun and is lost by month's end. Neptune is now an evening only planet, setting around midnight, followed by Uranus. The morning sees Mars gaining altitude, rising before dawn. Mercury is low, departing the morning sky as the year closes.

DEEP-SKY OBJECTS

Let's start with a nice wide double star, just eastward of the Large Magellanic Cloud (LMC). Eta[1] Doradus is a mag. +5.7 white, hot star. Nearby (0.7'NE) is the brighter (mag. +5.0) star, Eta[2], which is cooler and orange. Although the stars are visible to the unaided eye, binoculars are needed to see the colour contrast.

Although Dorado is best known for the LMC it's also home to a bright galaxy group, close to Alpha (α) Doradus. From this star head 2° west to the impressive spiral NGC 1566, then drop 2° south, passing into Reticulum, to NGC 1574 (RA 4hr 22m, dec. –56° 59'). Under reasonable power (200x) this mag. +10.4 elliptical galaxy shows a faint halo (1.5' across) with a small bright, diffuse core. There is a 10th magnitude star on its edge with an impressive 7th magnitude double star 0.3° east (mag. +6.8, 7.2 and 5" apart).

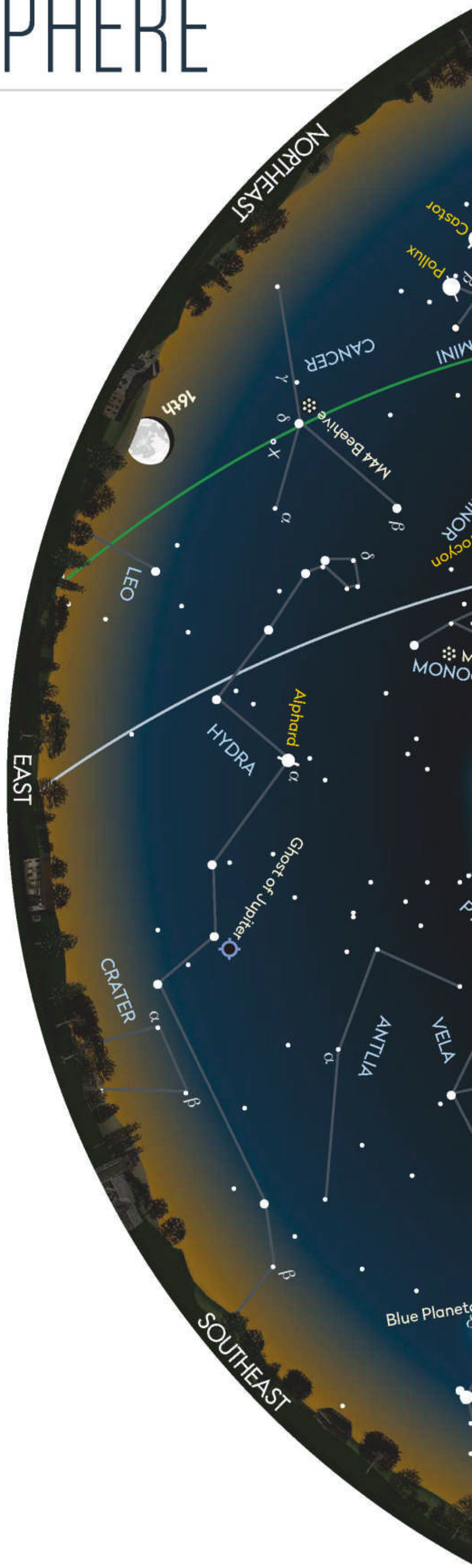
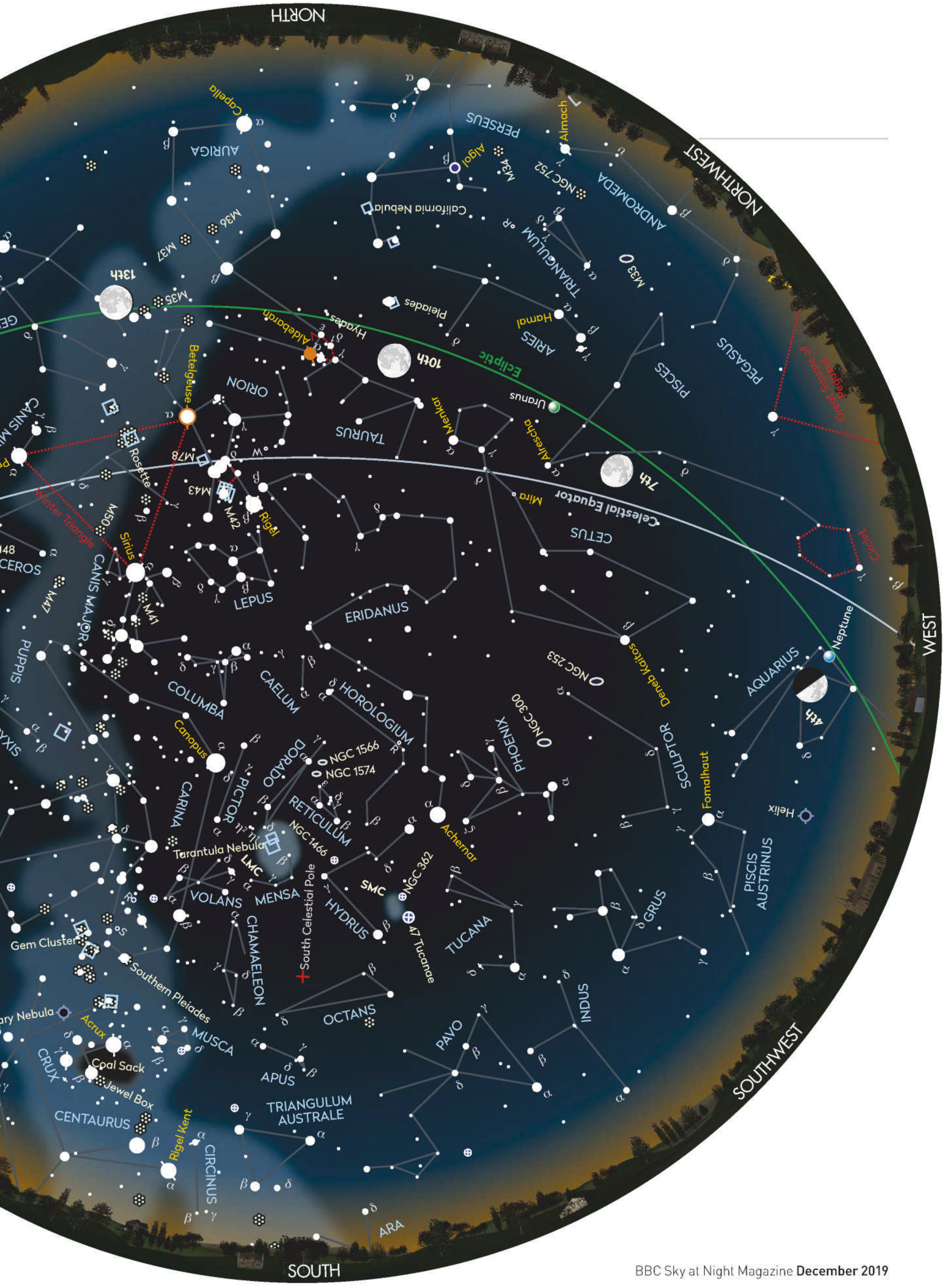


Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
AURIGA
PERSEUS
Algol
M34
Almach
NGC 752
ANDROMEDA
California Nebula
M36
M37
13th
M35
Pleiades
Hyades
Aldebaran
Hamal
ARIES
TRIANGULUM
M33
Ecliptic
10th
Betelgeuse
ORION
TAURUS
Uranus
Menkar
PISCES
PEGASUS
Great Square of Pegasus
Alpheratz
Algenib
Rosette
M78
M43
M42
Rigel
Winter Triangle
Sirius
M50
M47
M41
CANIS MAJOR
LEPUS
ERIDANUS
Mira
Celestial Equator
7th
Alrescha
CETUS
Deneb Kaitos
NGC 253
Circlet
Neptune
AQUARIUS
4th
PUPPIS
COLUMBA
CAELUM
HOROLOGIUM
Canopus
CARINA
PICTOR
DORADO
NGC 1566
NGC 1574
RETICULUM
NGC 1466
Tarantula Nebula
LMC
SMC
NGC 362
Achernar
PHOENIX
NGC 300
SCULPTOR
Fomalhaut
Helix
PISCIS AUSTRINUS
VOLANS
MENSA
HYDRUS
South Celestial Pole
47 Tucanae
TUCANA
GRUS
Gem Cluster
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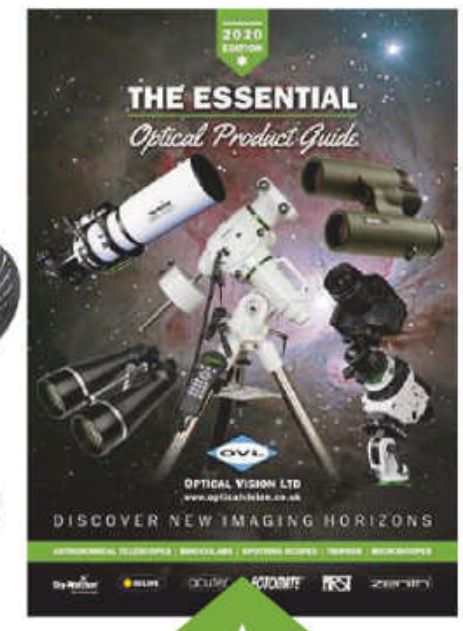

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